Fishery Data Series No. 15-14

Sonar Estimation of Chinook and Fall Chum Salmon Passage in the Yukon River near Eagle, Alaska, 2013

by

Jody Lozori

May 2015

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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SONAR ESTIMATION OF CHINOOK AND FALL CHUM SALMON PASSAGE IN THE YUKON RIVER NEAR EAGLE, ALASKA, 2013

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

ABSTRACT

Dual frequency identification sonar (DIDSON) and split-beam sonar equipment were used to estimate Chinook salmon *Oncorhynchus tshawytscha* and fall chum salmon *O. keta* passage in the Yukon River near Eagle, Alaska from July 6 to October 6, 2013. A total of 30,725 Chinook salmon were estimated to have passed the sonar site between July 6 and August 18. The midpoint of the Chinook salmon run occurred on July 26, which was 1 d late relative to the historical mean date of July 25. An estimated 200,754 fall chum salmon passed between August 19 and October 6. The sonar-estimated passage of fall chum salmon was subsequently expanded to a total passage estimate of 216,794 to include fish that may have passed after operations ceased. The midpoint of the fall chum salmon run, with and without the expansion, occurred on September 24, which was near the historical mean date of September 22. Subtracting the preliminary subsistence catch upstream of the sonar site, resulted in an estimated border passage of 30,573 Chinook salmon, and 204,149 fall chum salmon. A drift gillnet sample fishery was conducted to collect age, sex, length, and genetic information. Species composition was also recorded to determine when the Chinook salmon run ended and the fall chum salmon run began. Both sonar systems functioned well with minimal interruptions to operation. The range of ensonification was considered adequate for most fish that migrated upstream.

Key words: Alaska, Yukon River, Eagle, Chinook *Oncorhynchus tshawytscha*, chum salmon *Oncorhynchus keta*, dual frequency identification sonar, DIDSON, split-beam sonar, hydroacoustic.

INTRODUCTION

The Yukon River is the longest river in Yukon and Alaska, spanning 3,185 km. It flows northwester from its origin in northwestern British Columbia through the Yukon Territory and Central Alaska to its mouth at the Bering Sea. Commercial and subsistence fisheries harvest Chinook salmon *Oncorhynchus tshawytscha,* chum salmon *O. keta,* and coho salmon *O. kisutch* throughout most of the drainage. These fisheries are critical to the way of life and economy of people in dozens of communities along the river, in many instances providing the largest single source of food or income.

Fisheries management on the Yukon River is complex and difficult because of the number, diversity, and geographic range of fish stocks and user groups. Information upon which to base management decisions comes from several sources, each of which has unique strengths and weaknesses. Gillnet test fisheries provide inseason indices of run strength, but interpretation of these data are confounded by gillnet selectivity and the functional relationship between test fishery catches and abundance are poorly defined. Mark–recapture projects can provide estimates of total abundance but are not timely enough to make day-to-day management decisions. Sonar projects can provide timely estimates of abundance, but are limited in their ability to identify fish species.

Alaska is obligated to manage Canadian-origin Yukon River Chinook and fall chum salmon stocks according to precautionary, abundance-based harvest-sharing principles set by the *Yukon River Salmon Agreement* (Yukon River Panel 2004). The goal of bilateral, coordinated management is to meet negotiated escapement goals and provide for subsistence and commercial harvests of surplus in both the United States and Canada. Timely estimates of abundance help managers adjust harvest inseason and are crucial for postseason analysis to determine whether treaty obligations were met. The Canadian Department of Fisheries and Oceans (DFO) provided estimates of mainstem salmon passage through the U.S./Canada border using mark–recapture techniques from 1980 to 2008 (JTC 2013). Because of the highly turbid water of the Yukon River, and the width of the mainstem (approximately 400 m across at the study site), daily passage estimation methods that rely on visual observation, such as counting towers and weirs, are not feasible. Split-beam sonar technology are used successfully by the Alaska Department of

Fish and Game (ADF&G) to produce daily inseason estimates of salmon passage in turbid rivers, including the lower Yukon River at Pilot Station (Lozori and McIntosh 2013a). Dual frequency identification sonar (DIDSON[1]) has been used at several sites, including the Anvik River (McEwen 2013) and the Sheenjek River (Dunbar 2013), to give daily passage estimates where bottom profile and river width are appropriate for the wider beam angle and shorter range capabilities of this technology.

In 1992, ADF&G initiated a project near Eagle, Alaska (Figure 1) to examine the feasibility of using split-beam sonar to estimate the number of salmon migrating across the U.S./Canada border (Johnston et al. 1993; Huttunen and Skvorc 1994). This project was the first documented use of split-beam sonar in a riverine environment, and, over the 3-year duration of the study, a number of problems were identified. Phase corruption was observed and was probably exacerbated by the highly reflective river bottom (Konte et al. 1996). The errors in the phase measurement were believed to have resulted in overly restrictive echo angle thresholds causing the removal of echoes from fish that were physically within accepted detection regions. These and other equipment issues reflected the early state of split-beam development, most of which have since been addressed. These studies recommended a more appropriate site, with smaller rocks and a uniform bottom profile (Johnston et al. 1993). Too many large rocks or obstructions in the profile can compromise fish detection by limiting how close to the bottom the hydroacoustic beam can be aimed. Similarly, an uneven bottom profile permits fish to pass undetected by the sonar.

In 2003, ADF&G carried out a study to identify a more suitable location to deploy hydroacoustic equipment to estimate salmon passage into Canada. A 45 km section of river from the DFO mark–recapture fish wheel project at White Rock, Yukon Territory to 19 km downriver from Eagle, Alaska was explored (Pfisterer and Huttunen 2004). This area was investigated because of its proximity to the DFO project and the U.S./Canada border. Desirable characteristics included consistent, downward-sloping linear bottom profiles on both sides of the river without large obstructions; a single channel; available beach above the ordinary high water mark (OHW) for topside equipment; and sufficient current (i.e., areas without eddies or slack water where fish milling behavior can occur). A total of 21 river bottom transects led to potential project locations located between 9 km and 19 km downriver from the town of Eagle. The 2003 study identified Calico Bluff and Shade Creek as the most promising sonar deployment sites. Though sonar was not deployed in 2003, the bottom profiles at the preferred sites indicated that it should be possible to estimate fish passage with a combination of split-beam sonar on the longer, linear left bank and DIDSON on the shorter, steeper right bank. In 2004, ADF&G operated test sonars at the preferred sites over the course of 2 weeks. Both types of sonar were tested each site and it was found that Six Mile Bend (11.5 km downriver from the town of Eagle and immediately upstream of Shade Creek) was the most ideal site (Carroll et al. 2007a).

In 2005, a full-scale sonar project was conducted from July 1 to August 13 to estimate Chinook salmon passage in the Yukon River at Six Mile Bend (Carroll et al. 2007b). As suggested, DIDSON was deployed on the right bank, split-beam sonar was deployed on the left bank, and this equipment has since been used in subsequent years to estimate border passage for both Chinook and fall chum salmon.

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[1] Product brand names are included in this report for scientific completeness, but do not constitute product endorsement.

The project duration was extended in 2006 to provide an estimate of chum salmon passage. However, 2 genetically distinct runs of chum salmon enter the Yukon River, an early summer component and a later fall component (Estensen et al. 2013). Summer chum salmon spawn primarily in run-off streams in the lower 700 miles of the Yukon River drainage and in the Tanana River drainage. Fall chum salmon, which migrate past the Eagle sonar project, primarily spawn in the upper portion of the drainage in streams that are spring fed or geologically have major upwelling features. Major fall chum salmon spawning areas include the Tanana, Porcupine, and Chandalar river drainages as well as various streams in the Yukon Territory, Canada, including the mainstem Yukon River.

In 2013, the project deployed split-beam and DIDSON sonar to estimate Chinook and fall chum salmon passage migrating across the U.S./Canada border. Sample fisheries were conducted to determine the transition between Chinook and fall chum salmon runs, as well as collect age, sex, and length (ASL) and tissue samples for stock identification. This report will describe in detail the methodologies used to collect sonar and test fish data, as well as provide passage estimates, species distributions, run timing, in addition to climate and hydrologic observations.

OBJECTIVES

The primary goals of this project in 2013 were as follows:

1. Estimate the daily passage, seasonal passage, and run timing of Chinook and fall chum salmon using fixed-location split-beam and DIDSON sonar.
2. Use drift gillnets to estimate the end of Chinook salmon run and the beginning of the fall chum salmon run past the sonar site.
3. Collect a minimum of 160 Chinook salmon scale samples during each of 3 strata throughout the season to characterize the ASL composition of Yukon River Chinook salmon passage such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$).
4. Collect a minimum of 160 fall chum salmon scale samples during each of 4 strata throughout the season to characterize the ASL composition of Yukon River fall chum salmon passage such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$).
5. Collect Chinook and fall chum salmon tissue samples for genetic stock identification.
6. Collect daily climatic and hydrologic measurements representative of the study area.

METHODS

STUDY AREA

The study area is a 2 km section of the mainstem Yukon River at Six Mile Bend, 11.5 km downriver from Eagle, Alaska (Figure 2). Some additional drift gillnet fishing occurs farther downriver above Calico Bluff.

The Yukon River Basin is the fourth largest basin in North America, with a drainage area of 857,300 km^2 and an average annual discharge of 6,400 m^3/s. Flows are highest in June, with greatest variability in flow occurring in May, after which discharge and the variability in discharge decline. The upper Yukon River is turbid and silty in the summer and fall, with an estimated annual suspended sediment load at Eagle of 33,000,000 tons (Brabets et al. 2000).

Hungwitchin Native Corporation owns the majority of land in the study area above the OHW. Permission was granted to operate a sonar project on Hungwitchin land at Six Mile Bend. A semi-permanent field camp consisting of 6 canvas tents on plywood platforms was constructed in 2005 on the left bank (64°51′55.7″N, 141°04′43.6″W), and 2 additional tents were installed in 2012. An additional tent platform with a 12 ft x 15 ft Weatherport portable building was constructed on the left bank 1.3 km downriver from the camp (64°52′30.8″N, 141°04′52.8″W) to house computer and sonar related equipment. A portable wooden shelter was used on the right bank to house topside sonar equipment, a wireless router, and a solar powered battery bank.

HYDROACOUSTIC EQUIPMENT

A fixed-location, split-beam sonar developed by Kongsberg Simrad was used to estimate salmon passage on the left bank. Fish passage was monitored with a model EK60 digital echosounder, which included a general-purpose transceiver and a 2.5° x 10° 120 kHz transducer. ER60 data acquisition software, installed on a laptop computer connected to the echosounder, collected raw data for processing. Digital files created by the ER60 software were examined with the echogram viewer program Echotastic (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication), to produce an estimate of fish passage.

A DIDSON long-range unit, manufactured by Sound Metrics Corporation, was deployed on the right bank. This sonar was operated at 1.2 MHz (high frequency option using 96 beams) for the 0–20 m range and at 0.70 MHz (low frequency option using 48 beams) for the 20–40 m range. Both the low and high frequency modes have a viewing angle of 29° x 14°. A 60 m cable carried power and data between the DIDSON unit in the water and a topside breakout box. A wireless router transferred data between the breakout box and a laptop computer on the opposite bank. Sampling was controlled by DIDSON software loaded on the laptop computer. All surface electronics were housed on shore in a small, wood frame shelter. Right bank power was supplied by 12 V system consisting of an array of 4 solar panels (85 W), 10 batteries (6 V), a charge controller, and inverter. The solar power system was supplemented with a portable 2000 W gasoline generator and a power converter/charger. Left bank hydroacoustic equipment and computers were powered with a portable 2000 W gasoline generator running continuously.

SONAR DEPLOYMENT AND OPERATION

Each season, prior to transducer deployment, bottom profiles are checked to ensure the original sites remain acceptable for ensonification. Data were collected from transects made from bank-to-bank using a boat-mounted Lowrance LCX-15 dual-frequency transducer (down-looking sonar) with a built-in Global Positioning System (GPS). A bottom profile was then generated using data files uploaded to a computer and plotted with Microsoft® Excel (Figure 3).

The split-beam transducer was attached to 2 Hydroacoustic Technology Incorporated (HTI) model 662H single-axis rotators configured perpendicularly to provide dual-axis rotation. Aiming was performed remotely using a HTI model 660 remote control unit that provided horizontal and vertical positioning.

The split-beam sonar was deployed July 6 on the left bank. The transducer and rotators were mounted on a freestanding frame constructed of aluminum pipe and deployed approximately 15 m from shore (Figure 4). The frame was secured with sandbags and the transducer height was adjusted by sliding a mounting bar up or down along riser pipes that extended above the water. The transducer was deployed at approximately 1.0 m to 1.5 m depth and aimed perpendicular to the current along the natural substrate. The transducer was deployed at a location with consistent flow and no eddy or slack water. The split-beam system was aimed to ensonify a range of approximately 2 m to 150 m during the first half of the season when counting Chinook salmon and 2 m to 75 m during the second half of the season when counting fall chum salmon. Settings for data acquisition included 256 µs transmit pulse lengths, 500 W power output, 4.16 pings per second at 150 m range, and 8.33 pings per second at 75 m range.

A portable tripod-style fish lead was constructed approximately 1.5 m downstream from the transducer to prevent fish passage inshore of the transducer and provide sufficient offshore distance for fish swimming upstream to be detected in the sonar beam. A tripod was formed from 16 freestanding lead sections constructed of 2 in diameter steel pipes connected with adjustable fittings. Aluminum stringers, approximately 2.5 m long, were then attached horizontally to the upstream side of the tripods. The sections were finished with vertical lengths of aluminum conduit spaced 3.8 cm apart. Lead sections were placed side by side in the water at a distance between 5 m and 12 m beyond the transducer (Figure 5). The portability of this style of fish lead was important because of the gradual slope found on the left bank. As the water level rises and falls over the duration of the summer, the transducer and lead require frequent relocation to shallower or deeper water.

The DIDSON was deployed July 6 on the right bank and was mounted on an aluminum frame then aimed using a manual crank-style rotator (Figure 6). Operators adjusted the aim by viewing the video image and relaying aiming instructions to a technician on the remote bank via handheld VHF radio. Proper aim was achieved when adequate bottom features appeared over the majority of the ensonified range (0 m to 40 m).

A fish lead was constructed with 2 m steel "T" stakes and 4 ft plastic snow fencing with lead line strung through the bottom for weight. The fish lead was less than 1 m downstream from the transducer and extended 3 m offshore beyond the transducer. This distance provided sufficient offshore diversion for fish swimming upstream to be detected in the sonar beam. A short lead was appropriate for this bank because of the steep slope and short nearfield distance (0.83 m) of the DIDSON. The right bank was ensonified to a range of 40 m from the transducer, with 2 sampling zones, ranging from between 1–20 m and 20–40 m. Sonar control parameters included the following:

1) nearshore zone: 0.83 m window start, 20.01 m window length, high frequency mode, and 7 frames per second, and
2) offshore zone: 20.84 m window start, 20.01 m window length, low frequency mode, and 4 frames per second.

Sonar Data Processing and Passage Estimation

Split-beam data were collected continuously in 60 min increments and saved to an external hard drive for tracking and counting. The operator opened each data file in an echogram viewer program (Echotastic) and marked each upstream fish track with a computer mouse (Figure 7). The number of marks for each hour was saved as a text file, and recorded on a count form.

DIDSON data were collected in 30 min samples twice each hour of the day. For the first 30 min of every hour, the DIDSON sampled the ensonified range between 1 m and 20 m (Zone 1). For the second half of each hour, the DIDSON sampled between 20 m and 40 m (Zone 2). Upstream migrating fish were also counted in Echotastic. Upstream direction of travel was verified using the Echotastic video feature. These counts were saved as text files and recorded on a count form.

The actual count for each 30 min DIDSON sample was expanded for the full hour, and the estimated counts from Zone 1 and Zone 2 were summed for a total hourly count. The daily passage $\hat{y}$ for zone z on day d was calculated by summing the hourly passage rates for each hour as follows:

$$\hat{y}_{dz} = \sum_{p=1}^{24} \frac{y_{dzp}}{h_{dzp}}, \tag{1}$$

where h_{dzp} is the fraction of the hour sampled on day d, zone z, period p and y_{dzp} is the count for the same sample.

Treating the systematically sampled sonar counts as a simple random sample would yield an overestimate of the variance of the total, since sonar counts are highly autocorrelated. To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations was employed (Wolter 1985). The variance for the passage estimate for zone z on day d is estimated as:

$$\hat{V}_{y_{dz}} = 24^2 \frac{1-f_{dz}}{n_{dz}} \frac{\sum_{p=2}^{n_{dz}} \left(\frac{y_{dzp}}{h_{dzp}} - \frac{y_{dz,p-1}}{h_{dz,p-1}} \right)^2}{2(n_{dz}-1)}, \tag{2}$$

where n_{dz} is the number of samples in the day (24), f_{dz} is the fraction of the day sampled (12/24=0.5), and y_{dzp} is the hourly count for day d in zone z for sample p. Because passage estimates are assumed independent between zones and among days, the total variance was estimated as the sum of the variances:

$$\hat{V}ar(\hat{y}) = \sum_d \sum_z \hat{V}ar(\hat{y}_{dz}). \tag{3}$$

The counts from each split-beam and DIDSON sample were entered into a Microsoft® Excel spreadsheet where counts were adjusted for missing samples when data collection was interrupted. Brief interruptions intermittently occurred when routine maintenance (i.e., silt removal) or relocation of a transducer was required. Long-term interruptions also occurred when flooding or hazardous conditions forced removal of equipment.

Whenever a portion of a period or sample was missing on the either bank, passage was estimated by expansion based on the known portion of the sample. The number of minutes in a complete sample period m_s was divided by the number of minutes counted m_i, and then multiplied by the number of fish counted x in that period i. Passage y_i was estimated as

$$\hat{y}_i = x_i (m_s / m_i). \tag{4}$$

If data from 1 or more complete sample periods were missing, the actual count was expanded for the full day, where the number of hours in a complete day h_s was divided by the number of hours counted h_i and then multiplied by the number of fish counted x in that day d. Passage $\hat{y}_d$ was estimated as

$$\hat{y}_d = x_d \left(h_s / h_d \right) . \tag{5}$$

If data from 1 or more complete days x_d were missing, passage for each missing day y_d was estimated using simple linear interpolation based on the known passage y_b for the day immediately before the missing days and passage y_a for the day immediately after (x_a) the missing day(s) *as*

$$\hat{y}_d = y_b + x_d \left(\frac{y_a - y_b}{x_a} \right) . \tag{6}$$

As an example, if data from 9 d were missing, for the estimated passage on the third missing day ($d = 3$), $x_d = 3$, and $x_a = 10$.

After editing was complete, an estimate of hourly, daily, and cumulative fish passage was produced and forwarded to the Fairbanks ADF&G office via satellite telephone each day. The estimates produced during the field season were further reviewed postseason and adjusted as necessary.

If a large number of fall chum salmon were passing on the last day of sonar operation, the estimate was expanded using a second order polynomial equation, where y_i is the i^{th} daily passage estimate, L is the count on the last day of sonar operation, d is the total number of days expanding for, and x_i is the day number being estimated (where i = 1 through total number of days expanding for):

$$y_i = \frac{L}{d^2} \left(x_i - d \right)^2 . \tag{7}$$

Postseason, the U.S. portion of the Chinook and fall chum salmon subsistence harvest from the Eagle area upstream of the sonar site was subtracted from the adjusted sonar estimate to give a border passage estimate for each species.

SPATIAL AND TEMPORAL DISTRIBUTIONS

Fish range distributions for Chinook and fall chum salmon were examined postseason by importing text files containing all fish track information into R[2] where the fish counts were binned by range. The binned data was plotted in Microsoft® Excel to investigate the spatial distribution of fish passing the sonar site. Histograms of passage by hour were also created in Microsoft® Excel to investigate diel patterns of migration. Run timing of Chinook and fall chum salmon was examined inseason and postseason using information from the sonar estimate, fish range distribution, sample fishery catches, and local subsistence harvest.

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2 R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, available for download: http://www.R-project.org

SAMPLE FISHING

To monitor species composition and collect ASL and genetic samples, 2 sizes of gillnets (5.25 in and 7.5 in) were drifted through 3 zones: left bank inshore (LBI), left bank nearshore (LBN), and left bank offshore (LBF) (Figure 2). Nets were 25 fathoms long, approximately 25 ft deep, and hung "even" at a 2:1 ratio of web to corkline, with the exception that the inshore nets were approximately 8 ft deep (Table 1). Gillnet webbing consisted of Momoi MTC or MT, shade 11, double knot multifilament nylon twine.

Fishing for species composition and sample collection was conducted once daily from August 1 to September 30 between approximately 0800 and 1200 on the left bank. During the sampling period, both 5.25 in and 7.5 in nets were drifted twice within each of the 3 left bank zones (inshore, nearshore and offshore), for 12 drifts. Drifts were targeted to be 6 minutes in duration, but were occasionally shortened as necessary to avoid snags or to limit catches and thus prevent mortalities during times of high fish passage. The inshore zone drifts were referred to as "beach walks" (Fleischman et al. 1995), where 1 person held onto the shore end of the net and led it downstream along the beach while a boat drifted with the offshore end. The nearshore zone started approximately 1 net length from shore and the offshore zone started approximately 2 net lengths from shore (Figure 2). The order of drifts was 1) LBI, 2) LBN, and 3) LBF, with a minimum of 15 min between drifts in the same zone (Table 2). All drifts with 1 mesh size were completed before switching to another mesh size. Starting mesh sizes were alternated each day.

In an effort to collect more Chinook salmon ASL and genetic samples, additional fishing was conducted that targeted Chinook salmon. Between July 8 and July 31, fishing occurred twice per day from approximately 0800 to 1200 and again from approximately 1300 to 1700 to capture Chinook salmon. Between August 1 and August 15, Chinook salmon sample fishing was conducted once per day after species composition fishing was completed. Chinook salmon genetic and ASL samples were collected to estimate specific Canadian stock proportions and ASL composition of Chinook salmon entering Canada. On a rotating schedule, 4 different mesh sizes (5.25 in, 6.5 in, 7.5 in, and 8.5 in) were drifted over the course of the Chinook salmon run to effectively capture all size classes present (Table 2). Nets were 25 fathoms long, approximately 25 ft deep, and hung "even" at a 2:1 ratio of web to corkline. Three net sizes were drifted for approximately 6 min each within the left bank nearshore (LBN), left bank offshore (LBF), and right bank nearshore (RBN). During the 2013 season, The right bank zone was located approximately 2 km downriver from the sonar site where river conditions were suitable for drift gillnetting on that bank (Figure 2). This resulted in 9 drifts during the Chinook salmon sample fishing period. Each drift was recorded to the nearest second onto field data sheets: net start out SO, net full out FO, net start in SI, and net full in FI. For each drift, fishing time t, in minutes, was approximated as

$$t = SI - FO + \frac{FO - SO}{2} + \frac{FI - SI}{2} \quad (8)$$

Total effort f, in fathom-hours, of drift j with mesh size m during fishing period l in zone z on day d was calculated as

$$e_{dzfmj} = \frac{25\,t_{dzfmj}}{60}. \tag{9}$$

Captured salmon were sampled in the following ways:

For standard ASL samples, length was measured mideye to tail fork (METF) to the nearest 1 mm. Sex was determined by visually examining features such as development of the kype, roundness of the belly, presence or absence of an ovipositor, and overall size. This is similar to the sampling routine used on the Kuskokwim River (Molyneaux et al. 2010). Samples of 4 scales from Chinook salmon and 1 scale from fall chum salmon were removed from the preferred area of the fish[3] (Clutter and Whitesel 1956). All scale samples were cleaned and mounted on gum cards to be aged by ADF&G ASL lab in Anchorage. These scale data were used to estimate the age composition of salmon that pass the Eagle sonar site.

For genetic stock identification, an axillary process was clipped from each salmon. Chinook salmon samples were stored individually in a vial of ethanol, while fall chum salmon samples were stored in bulk collections of up to 200 samples. All samples were sent to ADF&G genetics laboratory and, from there, forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columbia for processing. Non-salmon species were measured from nose to tail fork but were not sampled for other data. Captured fish were handled in a manner that minimized mortalities. Most captured fish were quickly sampled and returned to the river.

Species Determination

Although the Chinook and fall chum salmon runs are considered discrete in time, some temporal overlap does occur. Inseason, a tentative date is chosen based on sonar counts, gillnet catches, and local harvest to represent the last day of the Chinook salmon run, with the remainder of the sonar estimates classified as fall chum salmon. After thorough examination of postseason fishery data, the tentative date may be adjusted to more accurately represent the run. This was determined by using reverse-cumulative Chinook catches and cumulative fall chum salmon catches. Estimates are reported as Chinook salmon for days d, such that:

$$\sum_{d=n,i=Chinook}^{d} C_{id} > \sum_{d=1,i=chum}^{d} C_{id}, \tag{10}$$

where n is most current day of fishing and C is the catch of species i on day d. The species crossover date is defined as the day where the inequality is no longer met.

With sparse catches and the possibility of outliers in the catch data, there was a concern that anomalous observations may have had a disproportionate effect in determining the crossover data using reverse cumulative analysis. Because of this, catch per unit effort (CPUE) from the species composition fishery and Friedman's smoothing algorithm (Friedman 1984) were also used to assess proportional abundance and as an indicator as to when the crossover date occurred. Traditional CPUE measures were calculated for each day d on the left bank b during

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[3] On the left side approximately 2 rows above the lateral line, in an area transected by a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Clutter and Whitesel 1956).

species composition fishing using 2 specific sizes of gillnet mesh g regardless of catch size. Chinook salmon CPUE was calculated on the catch c and effort e (calculated in equation 9) of the large mesh gillnet (7.5 in); fall chum salmon CPUE was calculated on the catch and effort of the small mesh gillnet (5.25 in). Since all nets were 25 fathoms (45.7 m) in length. CPUE estimates (in catch per fathom-hour) for each species i were made daily for the left bank species composition test fishery:

$$CPUE_{dbi} = \frac{\sum_g c_{dbig}}{e_{dbg}} \tag{11}$$

CPUE and catch data for Chinook and fall chum salmon were imported into *R* and scatter plots from the data were smoothed using Friedman's supersmoother algorithm (Friedman 1984). The algorithm, which computes 3 separate smooth curves from the input data with symmetric spans of 0.05**n*, 0.2**n* and 0.5**n*, where *n* was the number of data points, selects the best of the 3 smooth curves for each predicted point using leave-one-out cross validation. The best spans are then smoothed by a fixed-span smoother (span = 0.2**n*) and the prediction is computed by linearly interpolating between the 3 smooth curves. This final smooth curve is then smoothed again with a fixed-span smoother (span = 0.05**n*).

CLIMATE AND HYDROLOGIC OBSERVATIONS

Climatic and hydrologic observations were collected at approximately 1800 each day. Reported stream levels are taken from the U.S. Geological Survey's gaging station at Eagle, although water levels were carefully monitored at the sonar site as well. Surface water temperature was measured approximately 30 cm below the surface, with a HOBO U22™ water temperature data logger. The data logger was suspended from a float tied to the transducer stand and set to record every 4 h. Air temperature, wind velocity, and wind direction were measured daily with a Kestrel 2000 handheld weather meter. Other daily observations included occurrence of precipitation and percent cloud cover (Appendix A).

RESULTS

SONAR DEPLOYMENT

In 2013, both the right and left bank transducers were deployed in approximately the same locations that have been used in recent years. On July 6, the left bank sonar was deployed approximately 800 m downriver from the camp and the right bank sonar was deployed across the river approximately 700 m downriver from the camp (Figure 2). The left bank profile was approximately linear, extending approximately 300 m to the thalweg at a 2.2° slope. The right bank profile was less linear, shorter and steeper, extending approximately 100 m to the thalweg at a 6.0° slope (Figure 3). The substrate at Six Mile Bend was large cobble to small boulder on the right bank and small to medium sized cobble and silt on the left bank.

CHINOOK AND FALL CHUM SALMON PASSAGE ESTIMATION

Inseason, August 18 was tentatively determined to be the last day of the Chinook salmon run based on relatively low sonar counts and catches from the species composition test fishery. Fish range distribution from the sonar was also a primary indicator that the salmon run was changing from Chinook to fall chum salmon. This date was confirmed postseason after thorough examination of sample fishery information.

Analysis of reverse-cumulative Chinook and fall chum salmon catches indicate August 13 as the last day when the overall Chinook salmon catch was more than the overall fall chum salmon catch. To determine the crossover, Chinook and fall chum salmon catches were plotted by day, and the date was determined at the point where the 2 lines crossed when the number of fall chum salmon caught equaled the number of Chinook salmon (Figure 8). Because of low catches during the crossover transition, early catches of fall chum salmon shifted the crossover date back, although fall chum salmon were not observed between August 12 and August 19, and Chinook salmon were still being sampled in the test fishery.

Alternatively, CPUE and catch data for both the large and small mesh nets from the species composition test fishery were plotted, and the relationship between the variables summarized using the Friedman's supersmoother algorithm (Figures 9 and 10; Appendix B). Both plots suggest the last day of the Chinook salmon run was August 18. The supersmoother method seemed more reliable for determining the crossover date because of low catches and a continued Chinook salmon presence in the test fishery through August 18 (Figure 11). This method was used to determine the crossover date for the season.

The total passage estimate at the Eagle sonar site for Chinook salmon was 30,725 from July 6 to August 18, 2013. The first quarter point (July 21), midpoint (July 26), and third quarter point (August 1) indicated the midpoint of the Chinook salmon run occurred 1 d late when compared to 2005–2012 mean passage dates (Table 3 and Figure 12).[4] Peak daily passage estimate of 2,083 Chinook salmon occurred on July 20, and 147 fish passed on August 18, the last day of estimating Chinook salmon passage (Figure 13). Sampling time missed during this period because of routine maintenance, system diagnostic tests, system malfunction, moving and aiming the transducer, included 34.0 h on the left bank, 45.8 h on the right bank Zone 1, and 45.9 h on the right bank Zone 2. Sometimes the collection software from the split-beam sonar overran the sample time, resulting in a sample that was more than 1 h long. If at the end of a day the total sample time was more than 24 h (1,440 min), or in some cases, individual hours are composed of multiple files with a duration exceeding 1 h, the time in the table would show as negative. In this case, fish may have been subtracted from the estimate, resulting in a negative number of fish (Table 4).

Postseason, the subsistence Chinook salmon harvest from the Eagle area upstream of the sonar site was subtracted from the sonar estimate to produce a border passage estimate of 30,573 Chinook (Table 5). The preliminary subsistence harvest from the Eagle area upstream of the sonar was 152 Chinook salmon (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). This estimate is 41.3% below the 2005–2012 mean border passage estimate of 52,117 fish. This was also not enough to meet the interim management escapement goal (IMEG)[5] of 42,500–55,000 fish.

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4 Differences in the transition dates for species crossover confound computation of the historical daily cumulative and mean. As a convenience, the historical daily cumulative percent and mean were computed by assuming that 100% of the run was completed on the date the Chinook salmon run transitioned to fall chum salmon.

5 The US/Canada Yukon River Panel agreed to a 1-year Canadian interim management escapement goal (IMEG) of 42,500–55,000 Chinook salmon based on the Eagle sonar program. In order to meet this goal, the passage at Eagle sonar must include a minimum of 42,500 fish for escapement, provide for a subsistence harvest in the community of Eagle upstream of the sonar (approximately 1,000–2,000 fish), and incorporate Canadian harvest sharing as dictated in the US/Canada Yukon River Treaty (20%–26% of the total allowable catch).

The total fall chum salmon passage estimate was 200,754 fish from August 19 to October 6, 2013. The first quarter point (September 17), midpoint (September 24), and third quarter point (September 29), indicated the midpoint of the run occurred 2 d late when compared to 2006–2012 historical mean passage dates (Table 6 and Figure 12). Fall chum salmon passage peaked on September 25 with a daily estimate of 10,572 fish (Figure 13). Sampling time missed during this period because of routine maintenance, system diagnostic tests, system malfunction, moving and aiming the transducer, or environmental conditions, included 31.8 h on the left bank, 8.3 h on the right bank Zone 1, and 10.6 h on the right bank Zone 2 (Table 7). Although fall chum salmon passage was decreasing on the last day of operation, 4,564 fish (approximately 2.3% of total) passed on October 6 (Table 6). Continuing fall chum salmon passage when the project was terminated prompted expansion of the sonar estimate, which was adjusted to 216,794 fall chum salmon (Figure 13). The expansion was calculated using a second order polynomial equation extended to October 18. October 18 was chosen based on what is considered the most likely run timing scenario derived from 1982 to 2008 historical data collected at the DFO mark–recapture fish wheel project near the U.S./Canada border. After the end of season expansion was included in the fall chum salmon estimate, the first quarter point was September 17, the midpoint was September 24, and the third quarter point was September 30.

Postseason, the subsistence fall chum salmon harvest from the Eagle area upstream of the sonar was subtracted from the sonar estimate to produce a border passage estimate of 204,152 fish (Table 5). The preliminary subsistence harvest from the Eagle area was 12,642 fish (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). This estimate is 18.2% above the 2006 to 2012 mean border passage estimate of 172,663. The fall chum salmon escapement was estimated to be 199,800 fish[6] for the mainstem Yukon River in Canada, which exceeded the interim management escapement goal range of 70,000 to 104,000 fish and provided for harvest sharing agreement.

The objectives of estimating Chinook and fall chum salmon passage as well as run timing using split-beam and DIDSON sonar were achieved this season. Determination of a crossover date between Chinook and fall chum salmon migrations were successfully achieved through analysis of test fish data.

SPATIAL AND TEMPORAL DISTRIBUTION

Fish were shore-oriented on both banks (Figures 14 and 15). On the left bank during the Chinook salmon run, 95% of the fish were detected within 55 m of the transducer and 99% within 90 m. On the right bank, 95% of the fish were detected within 12 m of the transducer and 99% within 24 m. During the fall chum salmon run on the left bank, 95% of the fish were detected within 10 m of the transducer and 99% within 25 m. On the right bank, 95% of the fish were detected within 4 m of the transducer and 99% within 8 m. The percentage of fish passage estimated by bank for the Chinook salmon season was approximately 84% on the left bank and 16% on the right bank. During the fall chum salmon run, approximately 63% migrated on the left bank and 37% on the right bank.

Although Chinook salmon migration past the sonar does not suggest a diel migration pattern, an increase in passage on both banks was evident between 1100 and 1200 (Figure 16). This period

[6] The estimated mainstem Yukon River Canadian escapement is derived from the Eagle sonar estimate (expanded through October 18; 2008 to present) minus harvest from Eagle community upstream including Canadian harvests.

corresponds with the end of the morning test fishery, which suggests there may be a relationship between the fishing schedule and daily Chinook salmon passage.

Similarly, fall chum salmon passage on the left bank decreased during the morning test fishery, and again increased, leveling out after the fishery concluded. Contrary to the left bank passage, the right bank passage increased during the morning test fishery. It is noteworthy to mention that test fishing is not conducted on the right bank during a majority of the fall chum salmon run. Overall, when both banks are combined, there was a slight diel fluctuation as passage decreased slightly during the daylight hours (Figure 17).

SAMPLE FISHING

A total of 294 Chinook and 893 fall chum salmon were captured in drift gillnets between July 8 and September 30. Fishing for species composition and sample collection occurred from August 1 to September 30, and additional Chinook salmon sample fishing occurred from July 8 to August 15. Additionally, 3 sheefish *Stenodus leucichthys*, 2 Arctic grayling *Thymallus arcticus*, 1 whitefish *Coregoninae* spp., and 1 burbot *Lota lota* were captured during species composition fishing (Table 8). There were 0 Chinook and 2 fall chum salmon capture mortalities. Three Chinook salmon were observed to have clipped adipose fins indicating they held coded wire tags from the hatchery in Whitehorse, Yukon Territory. These fish were retained and the heads sent to the ADF&G Mark, Tag, and Age Lab in Juneau, Alaska.

Chinook salmon samples collected from driftnets included 144 (49.0%) males and 150 (51.0%) females. Fall chum salmon samples from driftnets included 548 (60.4%) males and 345 (39.0%) females. ASL samples from 294 Chinook and 877 fall chum salmon (Tables 9 and 10) were collected and sent to the ADF&G age determination laboratory in Anchorage, Alaska for processing. Genetic samples from 294 Chinook and 891 fall chum salmon (Tables 9 and 10) were collected and sent to the ADF&G genetics laboratory in Anchorage, Alaska and, from there, forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columbia for processing.

Because of low Chinook salmon catches this season, the objective to collect a minimum of 160 Chinook salmon scales samples during each of 3 strata was not met. The number of samples collected for each of the 3 strata were 67 (July 20), 173 (August 4), and 52 (August 18). The objective to collect 160 fall chum salmon scale samples within 4 strata also was not entirely achieved because of low catches at the beginning of the fall chum migration. The number of samples collected for each of the 4 strata were 22 (August 30), 169 (September 11), 486 (September 23), and 224 (October 6). Goals to collect Chinook and fall chum salmon tissue samples for genetic stock identification were achieved.

CLIMATE AND HYDROLOGIC OBSERVATIONS

Weather and water observations were recorded at the sonar site daily (Appendix A). Water temperature decreased over the course of the season, with a maximum daily recording of 19.5°C and a minimum of 2.0°C. The water level was high upon arrival at the project site on July 1 and remained higher than the 1995 through 2012 historic mean the entire season, with 2 brief exceptions: July 15–July 20 and August 16–August 18. The water level decreased over the duration of the season, with 1 temporary and dramatic increase starting approximately July 23. Overall, between July 1 and October 6 the water level decreased 7.3 ft from 20.8 ft to 13.5 ft. The lowest water level recorded during the season was 13.5 ft on October 6, while the highest was 21.1 ft on July 2 (Figure 18). All goals to collect climatic and hydrologic measurements were achieved this season.

DISCUSSION

The split-beam and DIDSON sonars performed well this season with no major technical difficulties or failures. There were periods between July 7 and July 10 when wireless connection failures were experienced transmitting DIDSON data, which resulted in the loss of approximately 21 h of data in both strata (Table 4). Considering the low passage during this time, the loss of data was insignificant (Table 3).

Snowfall on September 20 and September 22 increased surface noise, which diminished sonar detection on the left bank. Low passage estimates, compared to estimates prior to and after periods of heavy snowfall, indicated that the split-beam system was missing fish. Although there has been relatively little published on the effects of hydroacoustic sampling from the noise snowfall makes when striking water, studies have shown that some snowflakes make a characteristic sound analogous to the source signature for small raindrops (Alsarayreh 2008). Researchers have concluded that as a snowflake falls onto a body of water, it deposits a tiny amount of air just beneath the surface (Crum et al. 1999). Before the bubble reaches the surface and pops, it sends out a sound ranging from 50 to 200 kHz. Prosperetii[7] said that snowflake noise could create electronic "clutter" for people who use sonar devices to track migrating fish or to distinguish between natural and man-made underwater sounds. Signal strength was not considered dependable for fish counts during these periods, and passage estimates were interpolated.

It is uncertain why detection on the left bank was affected by snowfall while detection on the right bank was not. Likely, the split-beam system, which operates at a similar frequency to the noise snowflakes make, experienced acoustic interference. The interference may have limited the effective detection range of the split-beam, whereas the DIDSON was not as affected because of its higher operating frequency

During the Chinook salmon run, there were occasional problems distinguishing fish traces on the left bank from approximately 0 m to 25 m. Some fish traces were short in length and, at times, limited to a few pixels on echograms. The most logical explanation is the slow ping rate used with the split-beam sonar to reach the maximum range of the sampling strata (see Sonar Operation and Deployment section). Since the acoustic beam is narrow nearshore and widens with range offshore, fish move faster through the nearshore portion of the beam. Additionally, water velocities are slower nearshore, which also enables fish to move through the beam quicker. If the speed of a fish passing the transducer is high enough relative to the ping rate, it is probable that few or no echoes will be received from the fish, as they will be in the acoustic beam for a very short time, especially at short ranges (Ransom et al. 1999).

The counting software (Echotastic) was helpful in that threshold and configuration adjustments could be made to manipulate faint and short traces to determine directionality. Technicians paid particular attention to this range and adjusted echogram settings to identify short or faint fish

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[7] Headlines@Hopkins. 2000. Falling snow can create a noisy nuisance underwater, flakes produce bubbles that can disturb aquatic animals and disrupt sonar readings. Office of News and Information Johns Hopkins University, News Release, Baltimore Maryland [issued March 3, 2000]. Available from: http://www.jhu.edu/news_info/news/home00/mar00/flake.html (Accessed February 2014).

traces. Echo traces were counted if at least 2 pings passed the threshold level, and the targets did not resemble inert downstream objects.

To resolve this problem in the future, consideration is being made to divide the sampling range into 2 strata (0–50 m and 50–150 m) during the Chinook salmon run. Sampling periods would alternate sequentially between strata every 30 minutes. This will enable us to sample the near shore strata at a higher pulse repetition rate than the traditional setting. Unfortunately, custom software needs to be developed to control the sounder to alternate sequentially between strata, and at this time it is uncertain if this will be feasible with the split-beam sounder used at the project.

Alternatively and more costly, a DIDSON or ARIS (Adaptive Resolution Imaging Sonar) could be deployed, and run simultaneously with the split-beam to supplement counts in the near shore, similar to the enumeration methodology used on the lower Yukon River at the Pilot Station sonar project (Lozori and McIntosh 2013b). Recently the ARIS[8] sonar has been used on the Teslin (Mercer 2013), Kenai, and Tanana rivers to enumerate salmon escapement.

Significant swallowing on the right bank upstream of Calico Bluff prevented Chinook salmon sample fishing at the traditional site this season (Figure 2). In an effort to continue sampling Chinook salmon on the right bank, several alternate locations were explored below the sonar. Similar to years during the early stages of the project, frequent snagging of the net and strong currents were considered dangerous (Withler 2006), and locating both an effective and safe drift netting site on the right bank was challenging. Although the site that was selected this season had few snags and moderate current, the site did not prove effective in capturing Chinook salmon.

Considerations should be made to identify alternative test fish sites next season in the event that similar conditions are encountered. Excluding the site selected this year, no safe alternatives downstream of the sonar site have been identified. Cursory investigations of potential sites upstream of the sonar suggest fewer large boulders to snag and less current, but there is uncertainty of fish behavior after capture. Bernard et al. (1999) found evidence that adult Chinook salmon handled in riverine studies migrate differently upon release, and it is possible captured fish may move back downstream of the sonar, increasing the chance of detecting fish multiple times. However, this may not be a significant concern as the percentage of Chinook salmon catches are low compared to passage estimates (Figure 19). Nevertheless, if sites are considered upstream, they should be within a reasonable distance from the sonar yet far enough upstream so that fish have an opportunity to recover without reentering the sonar.

Alternative methods were examined this season to evaluate the crossover date and eliminate possible outliers and leverage points in the catch data, which were thought to have biased the reverse cumulative analysis. After evaluating curves from smoothed data, it was determined that using CPUE from the species composition test fishery was a better fit than reverse cumulative of catch to determine the crossover date. CPUE, which is usually assumed to be proportional to abundance (Hinton and Maunder 2003), seems more defensible in regard to predicting the crossover date, rather than assuming effort for both species is the same (Crane and Dunbar 2009). Although this method, when applied to previous years, does change those estimates (Table 11), at this time, revision of historical passage estimates is not anticipated. It is not within

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[8] Sound Metrics manufactures the ARIS sonar. The ARIS is considered the "second generation" model of high resolution sonars produced by this company.

the scope of this report to present complete findings of historic data analysis using smoothed CPUE data for species crossover, but findings will be presented in the future as a ADF&G, Division of Commercial Fisheries, AYK regional office memorandum (Appendix C).

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TABLES AND FIGURES

Table 1.–Specifications for drift gillnets used for test fishing at the Eagle sonar project on the Yukon River, 2013.

	Stretch mesh size		Mesh diameter	Meshes deep	Depth
Method	(in)	(mm)	(mm)	(MD)	(m)
Drift	5.25	133	85	69	8.0
	6.50	165	105	55	7.9
	7.50	191	121	48	8.0
	8.50	216	137	43	8.1
Beach walk	5.25	133	85	26	3.0
	7.50	191	121	18	3.0

Table 2.–Net schedules for species composition and additional Chinook salmon samples, all zones, at the Eagle sonar project on the Yukon River, 2013.

		Mesh size (inches)		
Sampling purpose	Day	Drift 1	Drift 2	Drift 3
Species composition	1	5.25	7.50	NA
	2	7.50	5.25	NA
Additional Chinook salmon samples	1	5.25	6.50	7.50
	2	7.50	8.50	6.50
	3	6.50	5.25	8.50
	4	8.50	7.50	5.25

Table 3.–Estimated daily and cumulative Chinook salmon passage by bank at the Eagle sonar project on the Yukon River, 2013.

	Daily			Cumulative			
Date	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage
7/06 [a]	0	2	2	0	2	2	0.00
7/07	2	7	9	2	9	11	0.00
7/08	0	10	10	2	19	21	0.00
7/09	0	11	11	2	30	32	0.00
7/10	2	5	7	4	35	39	0.00
7/11	10	13	23	14	48	62	0.00
7/12	12	14	26	26	62	88	0.00
7/13	25	14	39	51	76	127	0.00
7/14	47	38	85	98	114	212	0.01
7/15	92	93	185	190	207	397	0.01
7/16	239	176	415	429	383	812	0.03
7/17	535	210	745	964	593	1,557	0.05
7/18	824	342	1,166	1,788	935	2,723	0.09
7/19	1,294	326	1,620	3,082	1,261	4,343	0.14
7/20	1,837	246	2,083	4,919	1,507	6,426	0.21
7/21	1,752	312	2,064	6,671	1,819	8,490	0.28
7/22	1,789	162	1,951	8,460	1,981	10,441	0.34
7/23	1,673	249	1,922	10,133	2,230	12,363	0.40
7/24	1,414	177	1,591	11,547	2,407	13,954	0.45
7/25	1,005	102	1,107	12,552	2,509	15,061	0.49
7/26	967	88	1,055	13,519	2,597	16,116	0.52
7/27	1,099	178	1,277	14,618	2,775	17,393	0.57
7/28	1,263	189	1,452	15,881	2,964	18,845	0.61
7/29	1,077	119	1,196	16,958	3,083	20,041	0.65
7/30	935	195	1,130	17,893	3,278	21,171	0.69
7/31	955	235	1,190	18,848	3,513	22,361	0.73
8/01	900	196	1,096	19,748	3,709	23,457	0.76
8/02	857	196	1,053	20,605	3,905	24,510	0.80
8/03	854	176	1,030	21,459	4,081	25,540	0.83
8/04	677	85	762	22,136	4,166	26,302	0.86
8/05	611	80	691	22,747	4,246	26,993	0.88
8/06	528	58	586	23,275	4,304	27,579	0.90
8/07	371	68	439	23,646	4,372	28,018	0.91
8/08	297	54	351	23,943	4,426	28,369	0.92
8/09	267	74	341	24,210	4,500	28,710	0.93
8/10	262	72	334	24,472	4,572	29,044	0.95

-continued-

Table 3.–Page 2 of 2.

	Daily			Cumulative			
Date	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage
8/11	186	58	244	24,658	4,630	29,288	0.95
8/12	185	102	287	24,843	4,732	29,575	0.96
8/13	178	70	248	25,021	4,802	29,823	0.97
8/14	170	48	218	25,191	4,850	30,041	0.98
8/15	155	24	179	25,346	4,874	30,220	0.98
8/16	144	26	170	25,490	4,900	30,390	0.99
8/17	140	48	188	25,630	4,948	30,578	1.00
8/18 [b]	105	42	147	25,735	4,990	30,725	1.00
SE		82				82	

Note: The large boxed area identifies second and third quartile of run and inside bold box identifies median day of passage.

[a] Right and left bank sonar operational.

[b] Last day of Chinook salmon estimation.

Table 4.–Number of minutes by bank and day that were adjusted to calculate the hourly or daily Chinook salmon passage, and the resulting number of fish either added or subtracted from estimate at the Eagle sonar project on the Yukon River, 2013.

	Left bank (0–150 m)		Right bank (0–20 m)		Right bank (20–40 m)	
Date	Minutes	Fish	Minutes	Fish	Minutes	Fish
7/06	1,021.6	0	510.7	0	480.9	0
7/07	201.1	1	301.3	3	260.1	0
7/08	68.0	0	301.3	4	271.7	0
7/09	-47.4	0	181.6	3	181.9	0
7/10	151.3	0	486.2	3	543.6	0
7/11	9.2	0	32.0	1	2.6	0
7/12	92.8	0	3.7	0	41.6	0
7/13	2.1	0	20.3	0	20.4	0
7/14	-3.2	0	2.6	0	6.9	0
7/15	31.1	1	96.9	12	82.9	-1
7/16	0.6	-2	92.0	22	-18.6	0
7/17	9.5	0	1.5	0	14.1	0
7/18	10.1	1	9.7	4	31.1	0
7/19	8.9	1	1.0	0	1.3	0
7/20	9.0	9	31.1	10	31.1	0
7/21	8.9	8	33.5	14	37.6	0
7/22	-3.3	-11	2.7	0	11.4	0
7/23	-2.6	-5	62.2	21	39.7	0
7/24	68.4	64	58.7	7	82.0	0
7/25	50.0	29	2.1	0	2.6	0
7/26	2.4	-4	32.0	4	55.7	0
7/27	7.6	0	2.1	0	2.7	0
7/28	7.7	0	174.5	42	211.8	5
7/29	76.4	46	32.2	5	32.5	0
7/30	7.7	1	13.8	3	43.3	0
7/31	68.1	40	63.9	20	74.1	1
8/01	8.1	0	181.6	8	32.4	0
8/02	8.8	0	2.4	0	2.7	0
8/03	35.4	15	2.2	0	2.9	0
8/04	9.0	0	32.1	3	23.7	0
8/05	0.6	-5	2.1	0	2.9	0
8/06	9.6	0	2.5	0	20.6	0
8/07	10.7	0	2.4	0	2.7	0
8/08	9.7	0	2.1	0	2.9	0
8/09	10.2	0	71.5	6	32.6	0
8/10	10.7	0	2.1	0	2.8	0
8/11	9.7	0	2.2	0	2.8	0
8/12	9.7	0	30.7	0	32.5	0
8/13	9.6	0	2.2	0	2.9	0
8/14	10.5	0	2.1	0	2.8	0
8/15	9.7	0	2.1	0	2.9	0
8/16	4.9	0	2.3	0	32.6	0
8/17	9.6	0	2.3	0	3.0	0
8/18	9.8	0	2.2	0	2.7	0
Total	2,042.1 (34.0 h)	189	2747.0 (45.8 h)	186	2753.0 (45.9 h)	5

Note: Negative numbers are result of collection software over running the sample period.

Table 5.–Eagle sonar estimate, Eagle area subsistence harvest, and border passage estimates, 2005–2013.

	Sonar estimate		Eagle Area subsistence harvest		U.S. sonar mainstem border passage estimate	
Date	Chinook	chum	Chinook	chum	Chinook	chum
2005	81,528	ND	2,566	ND	78,962	ND
2006	73,691	236,386	2,303	17,775	71,388	218,611
2007	41,697	265,008 [a]	1,999	18,691	39,698	246,317
2008	38,097	185,409 [a]	815	11,381	37,282	174,028
2009	69,957	101,734 [a]	382	6,995	69,575	94,739
2010	35,074	133,413 [a]	604	11,432	34,470	121,498
2011	51,271	224,355 [a]	370	12,477	50,901	211,878
2012	34,747	153,248 [a]	91	11,681	34,656	141,567
2013	30,725	216,794[a]	152 [b]	12,642 [b]	30,573	204,152

Note: Estimates for subsistence caught salmon between the sonar site and border (Eagle area) prior to 2008 include an unknown portion caught below the sonar site. This number is most likely in the hundreds for Chinook salmon, and a few thousand for fall chum salmon. Starting in 2008, the estimates for subsistence caught salmon only include salmon harvested between the sonar site and the U.S./Canada border.

[a] Expanded sonar estimate, includes expansion for fish that may have passed after sonar operations ceased.

[b] Subsistence estimates for 2013 are preliminary.

Table 6.–Estimated daily and cumulative fall chum salmon passage by bank at the Eagle sonar project, on the Yukon River, 2013.

	Daily			Cumulative				
Date	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage	
8/19 [a]	115	34	149	115	34	149	0.00	
8/20	98	35	133	213	69	282	0.00	
8/21	144	26	170	357	95	452	0.00	
8/22	140	18	158	497	113	610	0.00	
8/23	156	30	186	653	143	796	0.00	
8/24	164	26	190	817	169	986	0.00	
8/25	233	32	265	1,050	201	1,251	0.01	
8/26	230	24	254	1,280	225	1,505	0.01	
8/27	294	28	322	1,574	253	1,827	0.01	
8/28	359	70	429	1,933	323	2,256	0.01	
8/29	551	80	631	2,484	403	2,887	0.01	
8/30	643	124	767	3,127	527	3,654	0.02	
8/31	862	212	1,074	3,989	739	4,728	0.02	
9/01	992	174	1,166	4,981	913	5,894	0.03	
9/02	1,093	234	1,327	6,074	1,147	7,221	0.04	
9/03	1,213	254	1,467	7,287	1,401	8,688	0.04	
9/04	1,275	378	1,653	8,562	1,779	10,341	0.05	
9/05	1,359	316	1,675	9,921	2,095	12,016	0.06	
9/06	1,438	328	1,766	11,359	2,423	13,782	0.07	
9/07	1,482	174	1,656	12,841	2,597	15,438	0.08	
9/08	1,552	94	1,646	14,393	2,691	17,084	0.09	
9/09	1,548	102	1,650	15,941	2,793	18,734	0.09	
9/10	1,585	64	1,649	17,526	2,857	20,383	0.10	
9/11	1,945	88	2,033	19,471	2,945	22,416	0.11	
9/12	1,861	158	2,019	21,332	3,103	24,435	0.12	
9/13	2,578	440	3,018	23,910	3,543	27,453	0.14	
9/14	4,305	668	4,973	28,215	4,211	32,426	0.16	
9/15	5,670	892	6,562	33,885	5,103	38,988	0.19	
9/16	6,412	1,460	7,872	40,297	6,563	46,860	0.23	
9/17	6,185	1,599	7,784	46,482	8,162	54,644	0.27	b
9/18	6,371	1,465	7,836	52,853	9,627	62,480	0.31	
9/19	4,393	2,027	6,420	57,246	11,654	68,900	0.34	
9/20	3,936	2,078	6,014	61,182	13,732	74,914	0.37	
9/21	4,027	3,438	7,465	65,209	17,170	82,379	0.41	
9/22	3,336	3,914	7,250	68,545	21,084	89,629	0.45	
9/23	2,901	5,483	8,384	71,446	26,567	98,013	0.49	
9/24	4,416	5,376	9,792	75,862	31,943	107,805	0.54	c
9/25	4,496	6,076	10,572	80,358	38,019	118,377	0.59	
9/26	4,090	4,901	8,991	84,448	42,920	127,368	0.63	
9/27	6,463	2,670	9,133	90,911	45,590	136,501	0.68	
9/28	6,432	2,665	9,097	97,343	48,255	145,598	0.73	
9/29	5,837	2,713	8,550	103,180	50,968	154,148	0.77	
9/30	4,969	3,487	8,456	108,149	54,455	162,604	0.81	

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Table 6.–Page 2 of 2.

Date	Daily			Cumulative			
	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage
10/01	3,398	3,774	7,172	111,547	58,229	169,776	0.85
10/02	4,316	3,624	7,940	115,863	61,853	177,716	0.89
10/03	3,115	3,800	6,915	118,978	65,653	184,631	0.92
10/04	2,798	3,282	6,080	121,776	68,935	190,711	0.95
10/05	2,730	2,749	5,479	124,506	71,684	196,190	0.98
10/06 [b]	2,216	2,348	4,564	126,722	74,032	200,754	1.00
SE [c]		710				710	

Note: The large boxed area identifies second and third quartile of run and inside bold box identifies median day of passage. The median is based on inseason sonar estimates and does not include postseason expansion.

[a] First day of fall chum salmon counts.

[b] Last day of sonar operation.

[c] Sampling error associated with the left bank was treated as insignificant since data was collected 24 h per day over the sampling range.

Table 7.–Number of minutes by bank and day that were adjusted, to calculate the hourly or daily fall chum salmon passage, and the resulting number of fish either added or subtracted from estimate at the Eagle sonar project on the Yukon River, 2013.

	Left bank (0–75 m)		Right bank (0–20 m)		Right bank (20–40 m)	
Date	Minutes	Fish	Minutes	Fish	Minutes	Fish
8/19	9.9	0	2.3	0	2.7	0
8/20	18.6	1	32.3	1	46.4	0
8/21	13.7	0	2.3	0	2.7	0
8/22	0.2	0	2.4	0	2.9	0
8/23	0.2	0	2.5	0	3.0	0
8/24	0.7	0	2.4	0	2.9	0
8/25	0.2	1	2.4	0	2.8	0
8/26	188.5	26	3.8	0	34.2	0
8/27	30.9	8	6.1	0	6.9	0
8/28	20.5	7	6.2	0	6.9	0
8/29	0.7	2	6.1	0	6.9	0
8/30	23.2	7	6.7	0	6.7	0
8/31	7.9	4	6.3	0	7.4	0
9/01	1.6	5	6.4	0	7.0	0
9/02	0.5	5	5.9	0	6.6	0
9/03	0.9	-1	6.0	0	6.3	0
9/04	2.1	13	6.0	0	6.6	0
9/05	0.4	-9	34.4	14	35.0	0
9/06	0.5	-9	2.4	0	2.7	0
9/07	21.8	21	-13.8	-6	42.4	0
9/08	11.1	8	2.2	0	2.7	0
9/09	1.3	-4	2.2	0	2.8	0
9/10	15.7	17	2.2	0	2.8	0
9/11	7.0	15	2.3	0	3.0	0
9/12	2.6	2	2.4	0	2.6	0
9/13	5.4	8	2.4	0	2.8	0
9/14	4.9	7	2.5	0	2.9	0
9/15	9.1	35	2.2	0	2.6	0
9/16	12.1	55	2.1	0	3.0	0
9/17	10.4	41	2.3	1	2.5	0
9/18	-0.3	22	2.2	1	2.6	0
9/19	-7.1	-8	2.3	5	3.1	0
9/20	141.2	361	2.3	4	2.7	0
9/21	28.4	189	2.4	10	2.7	0
9/22	468.9	1052	2.3	10	2.8	0
9/23	17.5	129	2.4	17	2.8	0
9/24	6.4	123	32.0	236	35.5	0
9/25	252.6	858	2.2	20	2.7	0
9/26	67.1	334	2.2	15	2.7	0
9/27	20.5	90	2.4	8	2.6	0
9/28	9.4	27	2.4	7	3.1	0
9/29	9.4	28	2.5	9	2.8	0
9/30	18.6	62	2.3	11	2.7	0
10/01	134.6	303	177.7	972	152.4	0
10/02	58.0	158	32.2	160	19.2	0
10/03	30.8	65	72.6	356	92.3	0
10/04	198.9	389	2.2	2	3.1	0
10/05	16.8	33	2.2	3	2.8	0
10/06	16.3	25	2.3	2	32.7	0
Total	1909.9 (31.8 h)	4,505	500.6 (8.3 h)	1,858	637.9 (10.6 h)	0

Note: Negative numbers are result of collection software over running sample period.

Table 8.–Fish caught with gillnets at the Eagle sonar project, on the Yukon River, 2013.

Species	Species composition fishing	Chinook salmon sample fishing	Total
Chinook salmon	70	224	294
Fall chum salmon	893	0	893
sheefish	3	0	3
whitefish	1	0	1
burbot	1	0	1
grayling	2	0	2
Total	970	224	1,194

Table 9.–Species composition fishing effort, catch, and percentage by zone and mesh for Chinook and fall chum salmon, by zone and mesh size, at the Eagle sonar project, 2013.

	Mesh size	Effort	Chinook		Chum	
Zone	(inches)	(fathom-hours)	Catch	Percent	Catch	Percent
LBI	5.25	334.39	12	17	647	72
	7.50	300.49	5	7	179	20
Total		634.88	17	24	826	93
LBN	5.25	328.05	12	17	38	4
	7.50	329.48	39	56	26	3
Total		657.53	51	73	64	7
LBF	5.25	317.87	0	0	2	0
	7.50	328.65	2	3	1	0
Total		646.52	2	3	3	0
Grand total		1,938.93	70	100	893	100

Note: LBI = left bank inshore, LBN = left bank nearshore, LBF = left bank offshore.

Table 10.–Chinook salmon sample fishing effort, catch, and percentage for Chinook and fall chum salmon, by zone and mesh size, Eagle sonar project, 2013.

	Mesh Size	Effort	Chinook		Chum	
Zone	(inches)	(fathom-hours)	Catch	Percent	Catch	Percent
LBN	5.25	132.71	46	21	0	0
	6.50	128.05	58	26	0	0
	7.50	137.18	51	23	0	0
	8.50	129.25	46	21	0	0
Total		527.19	201	90	0	0
RBN	5.25	123.48	2	1	0	0
	6.50	119.83	5	2	0	0
	7.50	128.60	5	2	0	0
	8.50	119.33	3	1	0	0
Total		491	15	7	0	0
LBF	5.25	121.47	1	0	0	0
	6.50	121.09	1	0	0	0
	7.50	129.52	2	1	0	0
	8.50	119.15	4	2	0	0
Total		491	8	3	0	0
Grand total		1,509.66	224	100	0	0

Note: LBN = left bank nearshore, RBN = right bank nearshore, LBF = left bank offshore.

Table 11.–Comparison of reverse cumulative and smoothed CPUE crossover data at the Eagle sonar project, on the Yukon River.

	Reverse cumulative crossover date	Smoothed CPUE crossover date	Chinook salmon		Chum salmon[a]	
			Reverse cumulative passage estimate	Smoothed CPUE passage estimate	Reverse cumulative passage estimate	Smooth CPUE passage estimate
2007[b]	8/22	9/1	41,697	43,126	235,871	234,442
2008	8/16	8/11	38,097	35,395	171,347	174,049
2009	8/20	8/12	69,957	68,780	95,462	96,639
2010	8/19	8/16	35,074	34,364	125,547	126,257
2011	8/12	8/13	51,271	51,503	212,162	211,930
2012	8/19	8/21	34,747	35,009	147,710	147,448
2013	8/13	8/18	29,823	30,725	201,656	200,754

Note: CPUE is catch per unit effort.

[a] Estimates do not include expansion for fish that may have passed after sonar operations ceased.

[b] First year reverse cumulative was used to determine crossover date.

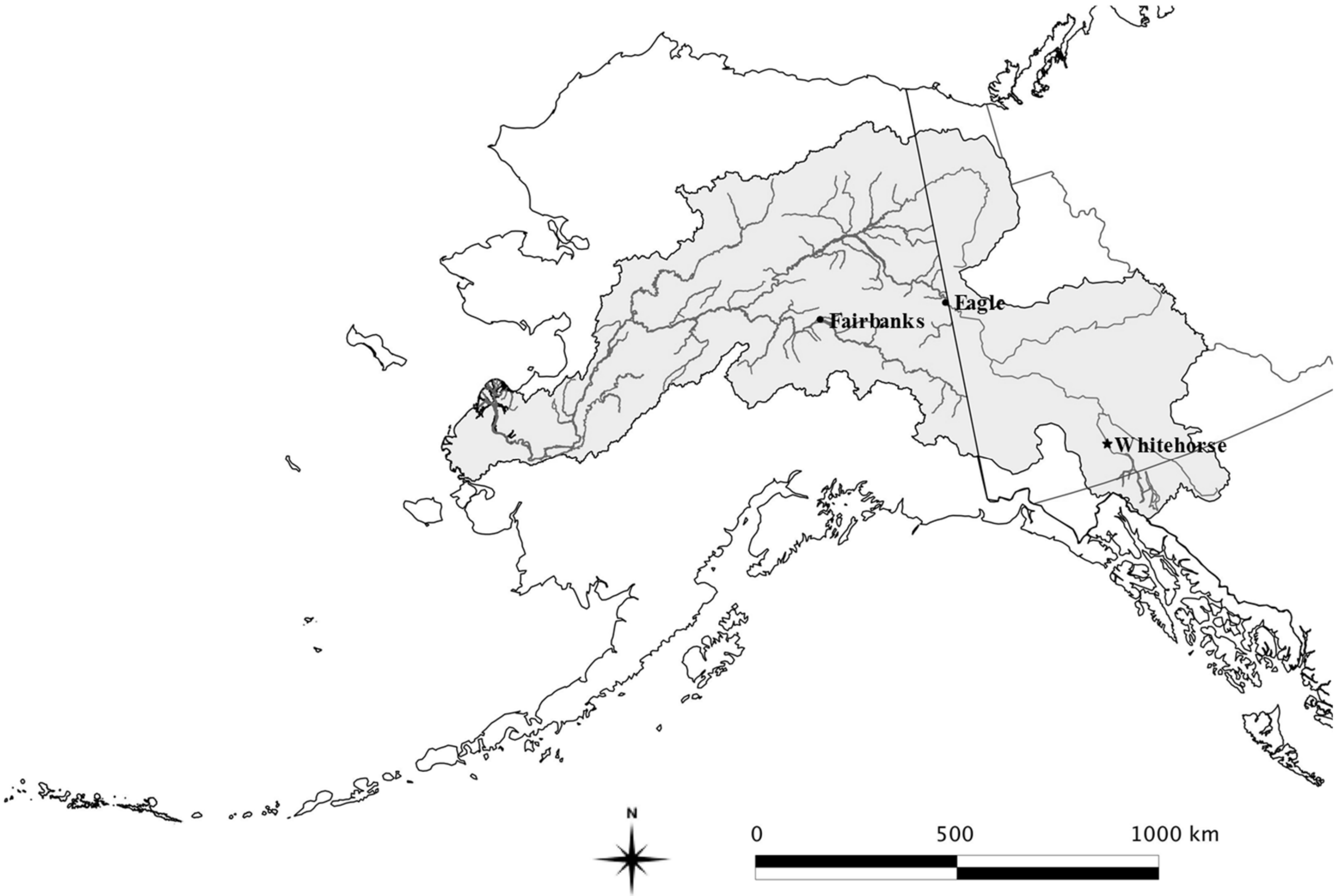


Figure 1.–Yukon River drainage.

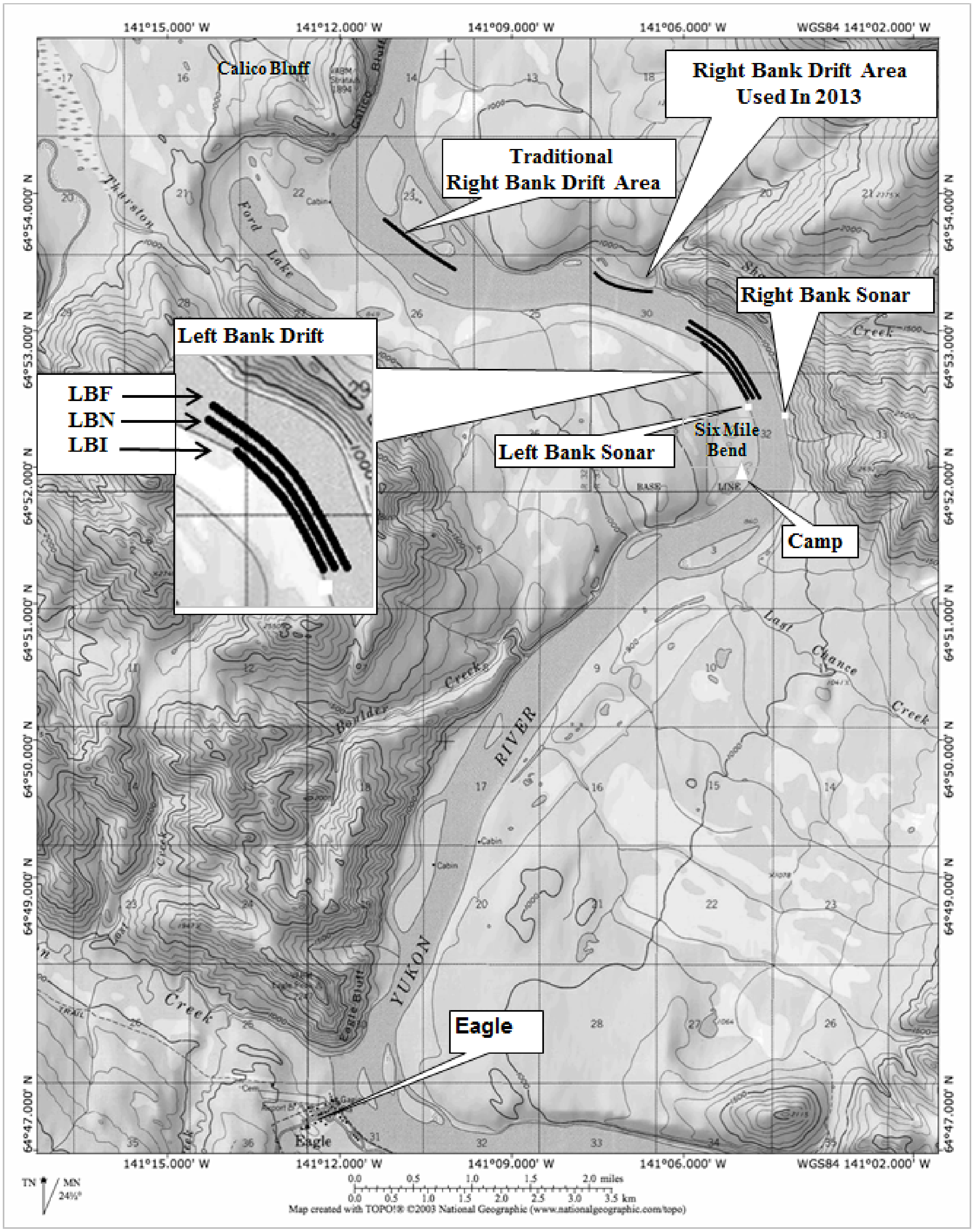


Figure 2.–Eagle sonar project site at Six Mile Bend, showing sonar and drift gillnet fishing locations.

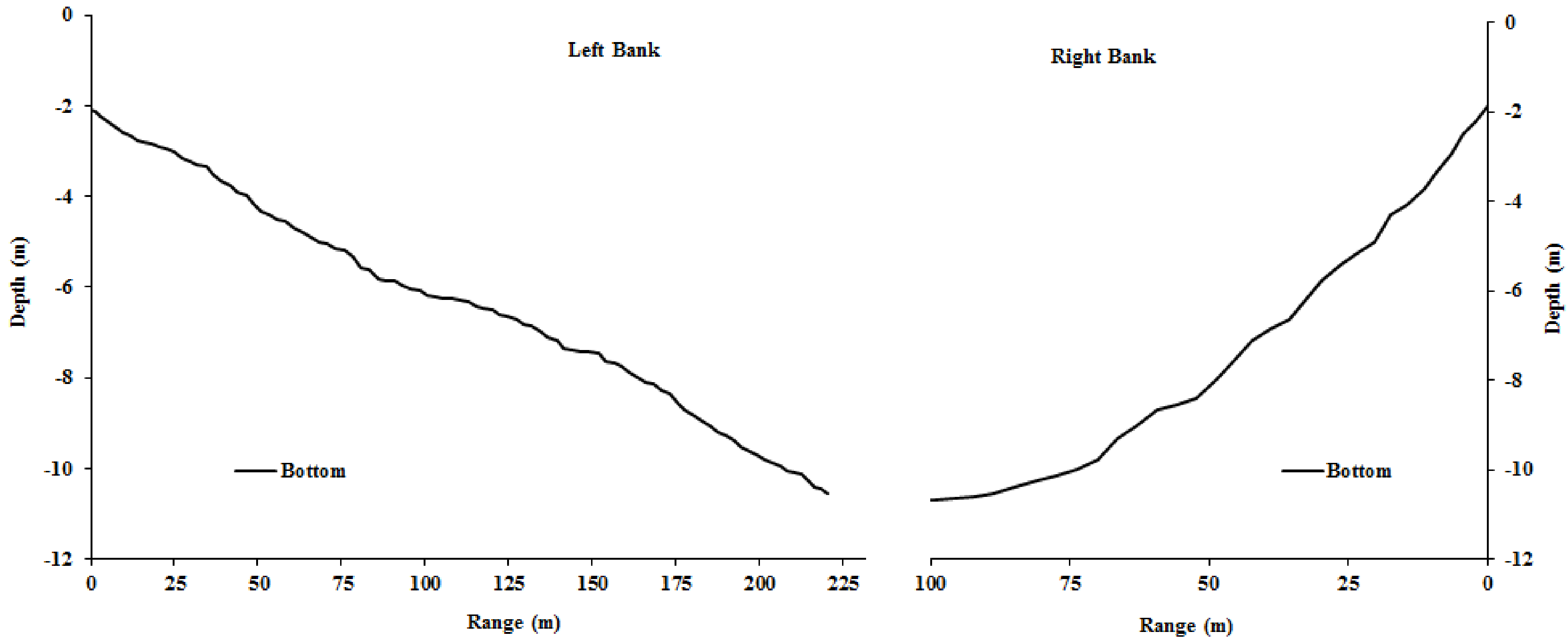


Figure 3.–Depth profile (downstream view) of Yukon River, at Eagle sonar project, 2013.

Note: To avoid damage to the outboard motor and transducer, bathymetric data collection began offshore at a depth of approximately 2 m.

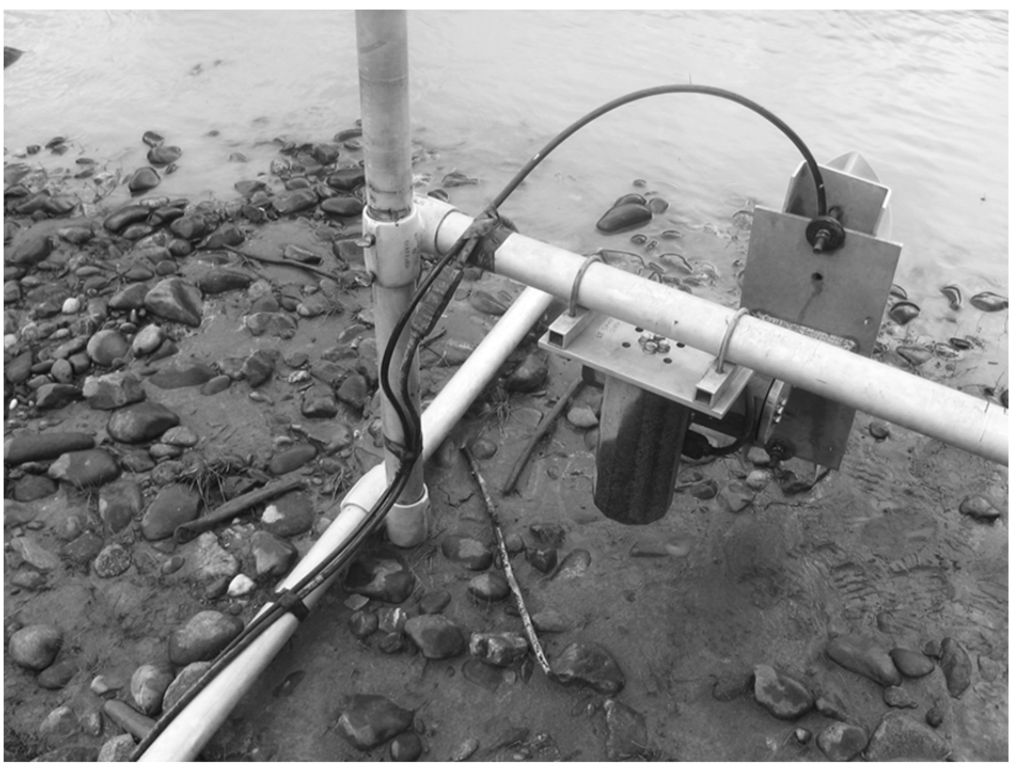


Figure 4.–Split-beam transducer mounted to an aluminum H-mount (top) and the same transducer mounted to 2 single axis automated rotators (bottom), used on the left bank at the Eagle sonar project, on the Yukon River, 2013.

Figure 5.–Portable tripod-style fish lead used on the left bank at the Eagle sonar project, on the Yukon River, 2013.

Figure 6.–View of a DIDSON mounted to aluminum H-mount with manual crank-style rotator at the Sheenjek sonar project. This mount is comparable to the one used at the Eagle sonar project, on the Yukon River.

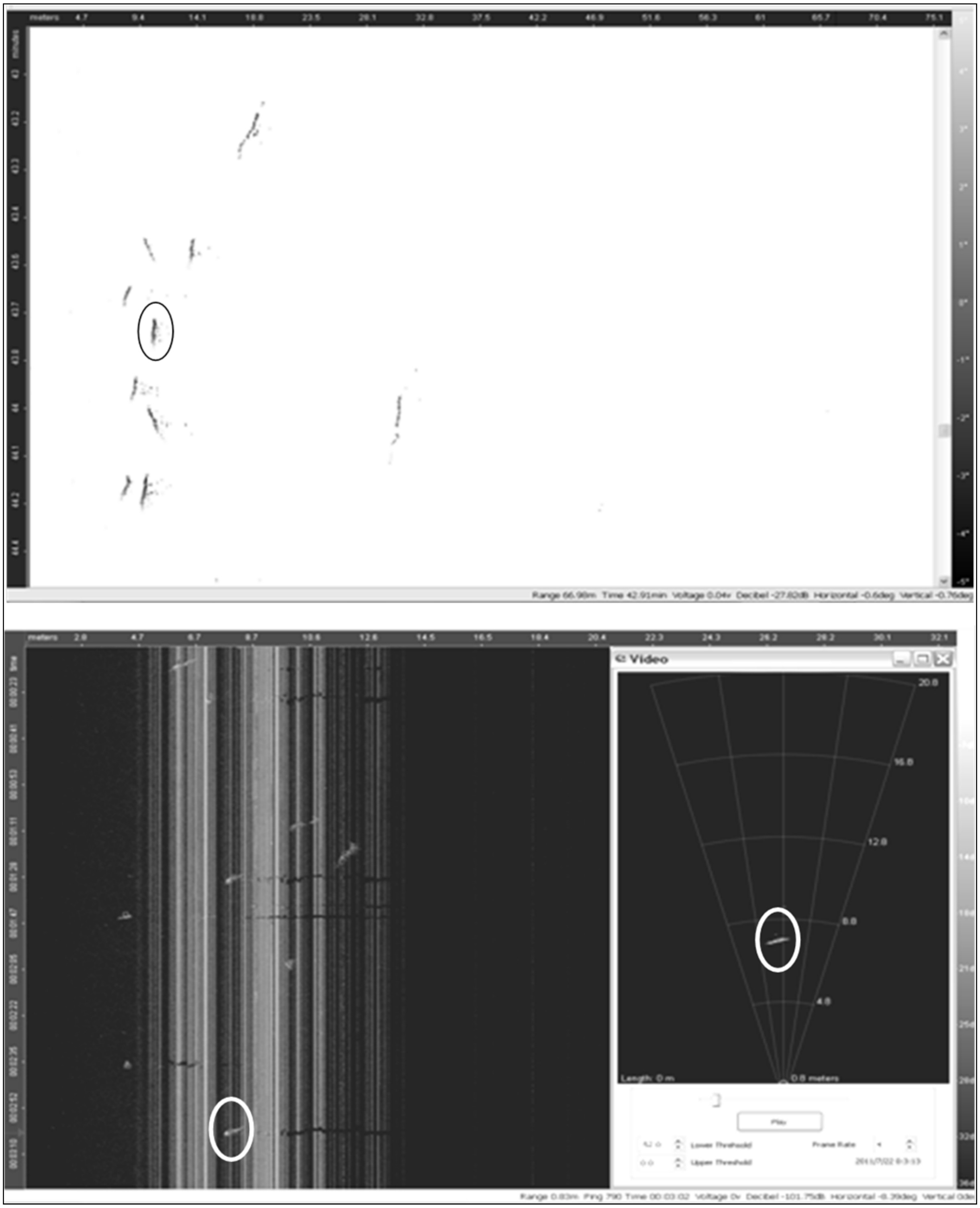


Figure 7.–Screenshots of echograms used to count fish from split-beam sonar data files (top), and DIDSON data files (bottom) at the Eagle sonar project, on the Yukon River, 2013.

Note: Ellipse encompasses typical upstream migrating salmon.

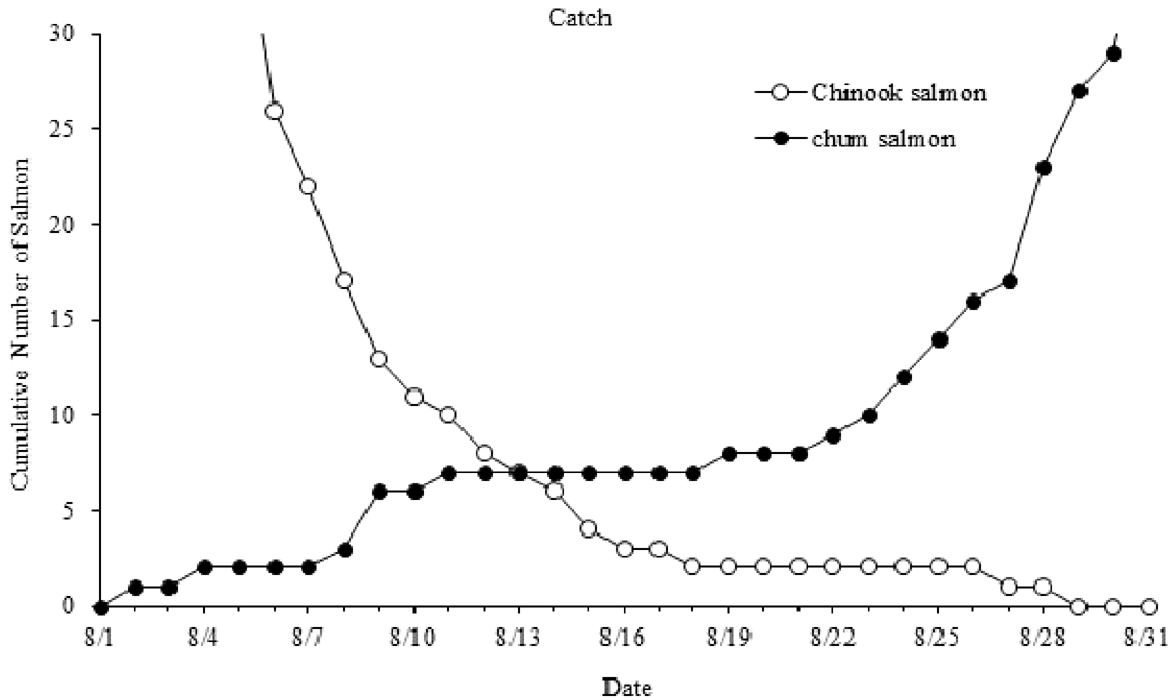


Figure 8.–The species changeover date (August 13) as determined from reverse cumulative Chinook and fall chum salmon catches at the Eagle sonar project, on the Yukon River, 2013.

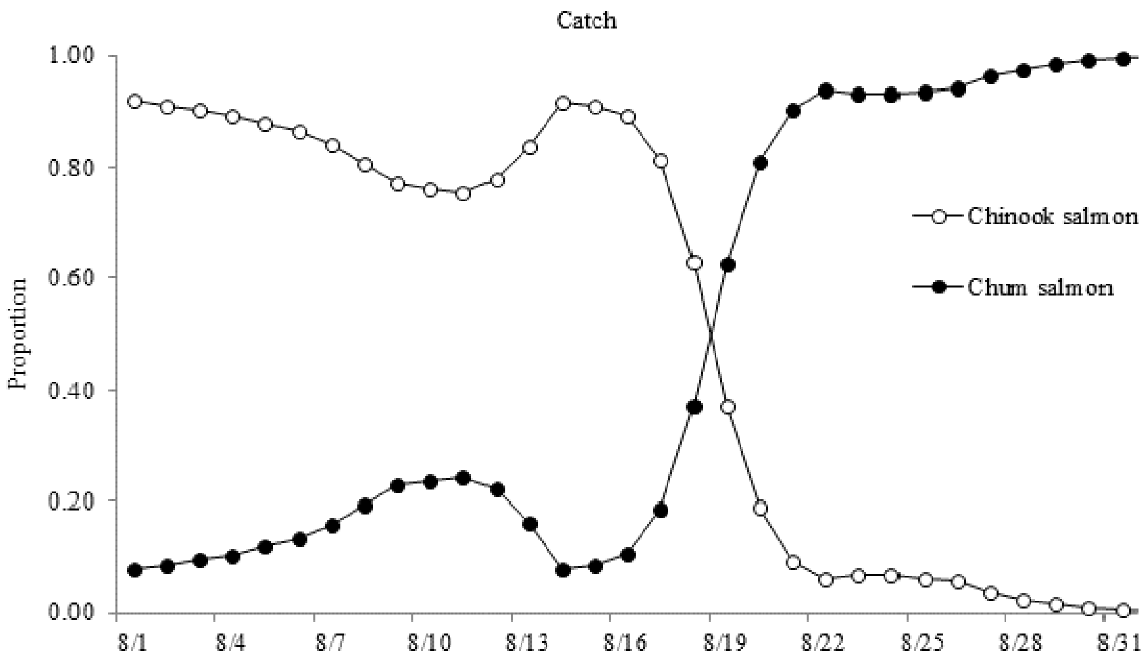


Figure 9.–The species changeover date (August 18) as determined by applying smoothing algorithm to Chinook and fall chum salmon species composition test fishery catch data at the Eagle sonar project, on the Yukon River, 2013.

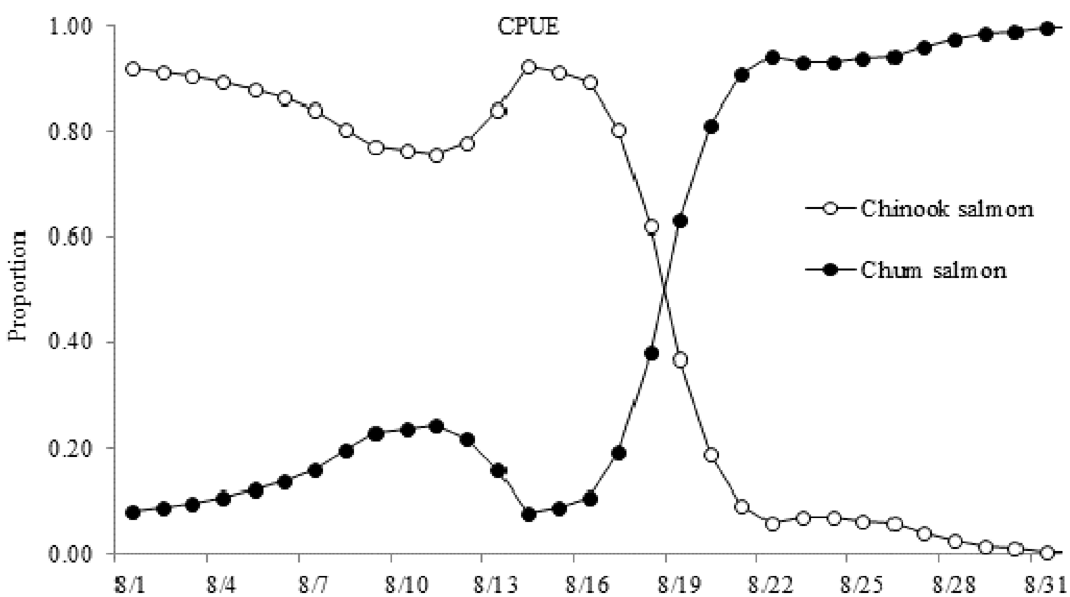


Figure 10.–The species changeover date (August 18) as determined by applying smoothing algorithm to Chinook and fall chum salmon species composition test fishery catch per unit effort (CPUE) data at the Eagle sonar project, on the Yukon River, 2013.

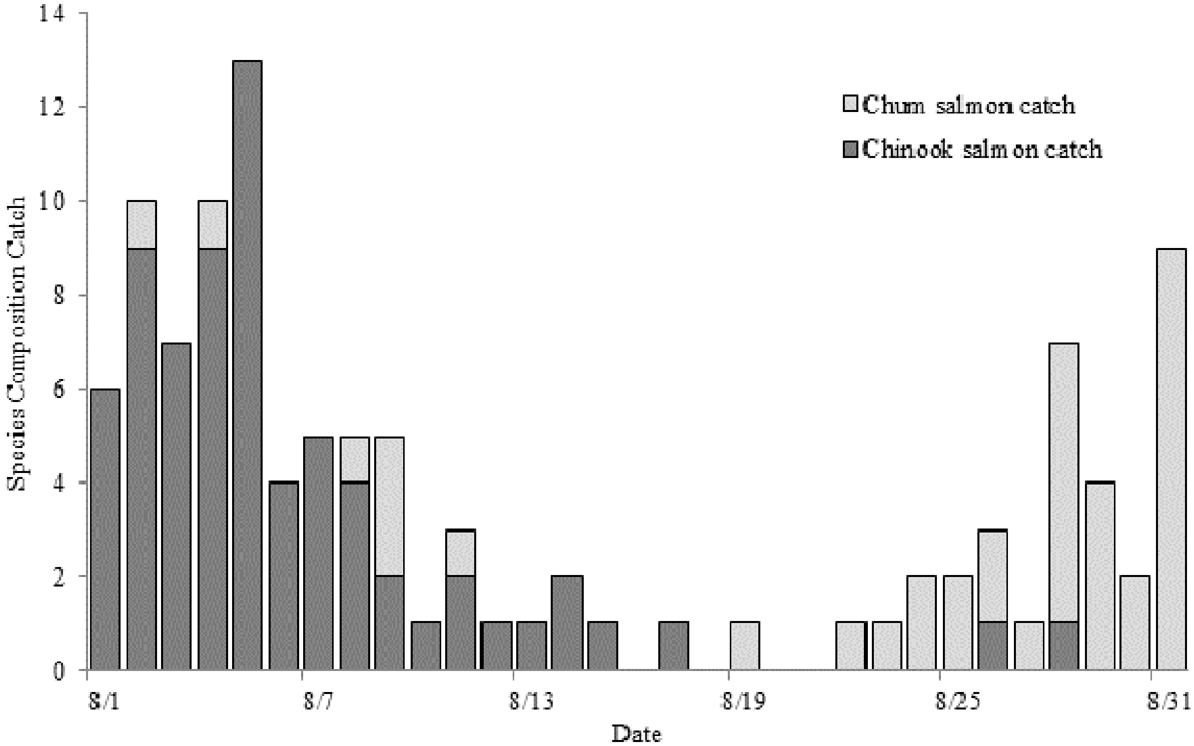


Figure 11.–Daily catch by species during species composition fishing at the Eagle sonar project, on the Yukon River, 2013.

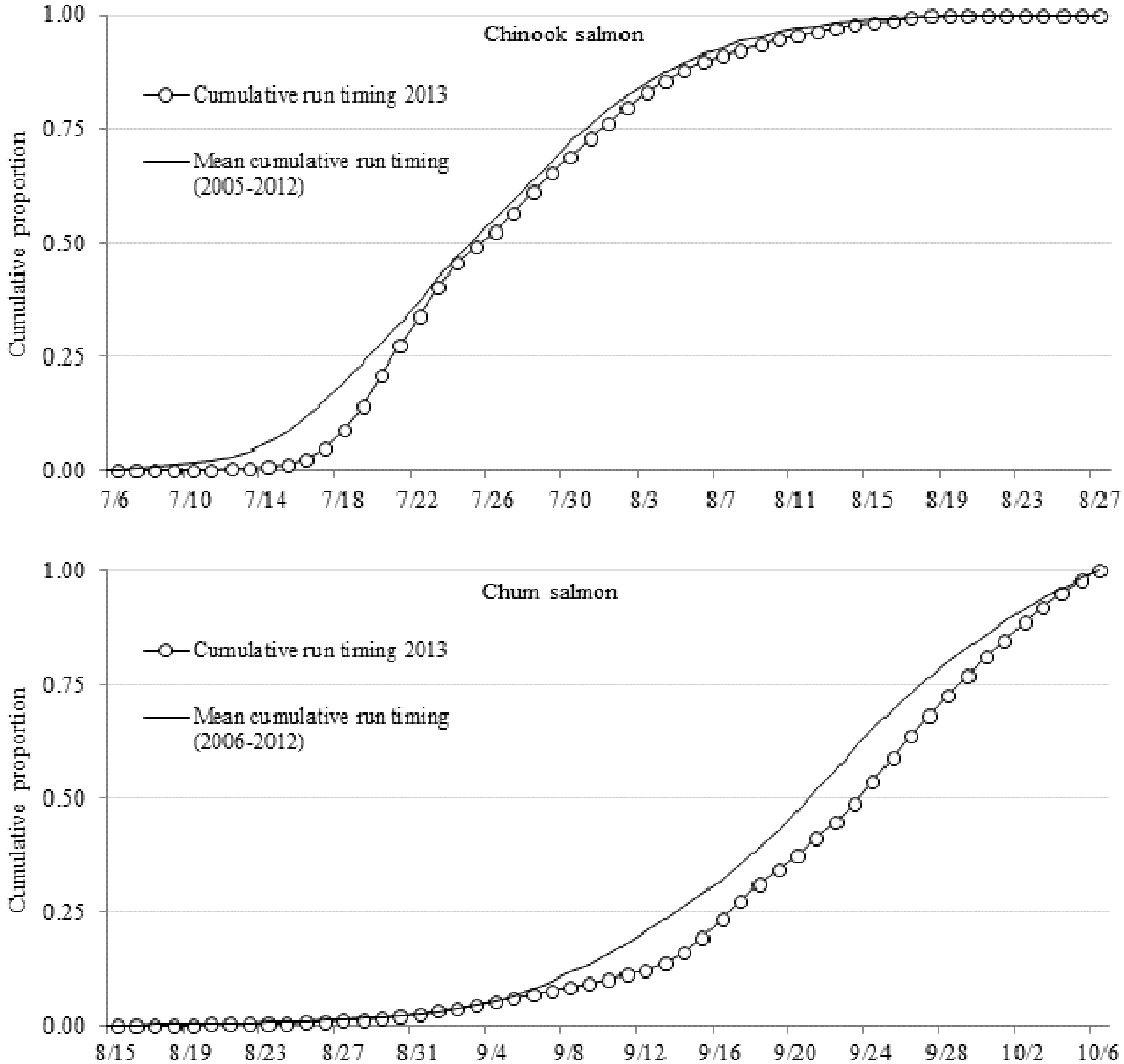
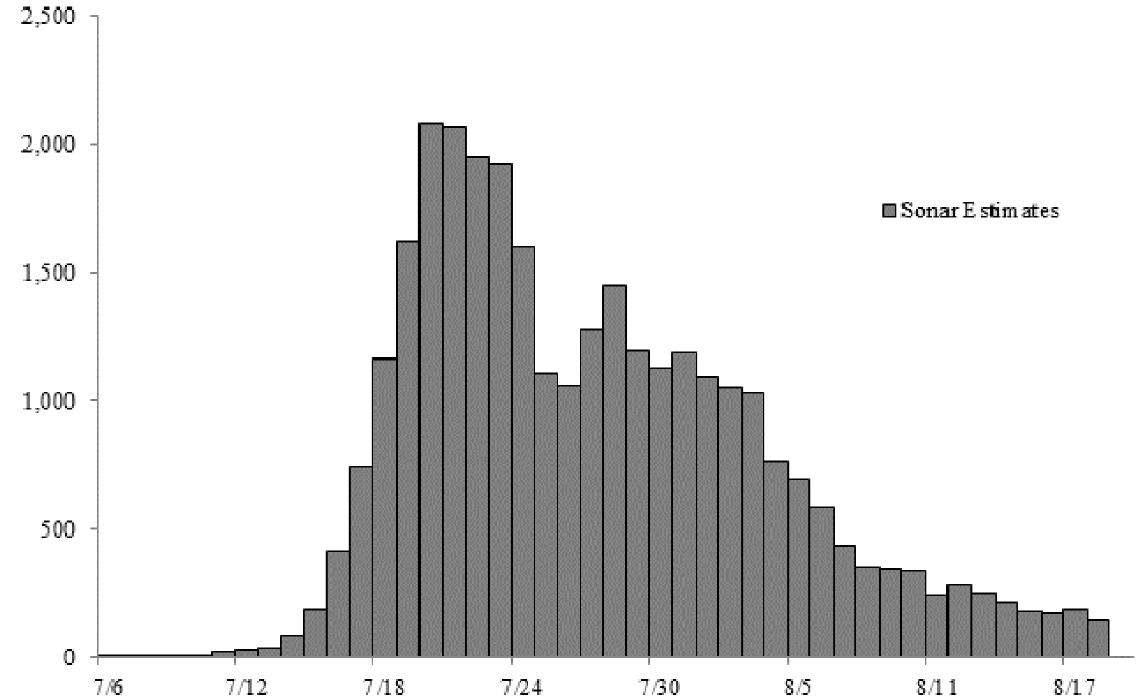


Figure 12.–The 2013 Chinook and fall chum salmon daily cumulative passage timing, compared to the 2005–2012 mean passage timing at the Eagle sonar project, on the Yukon River.



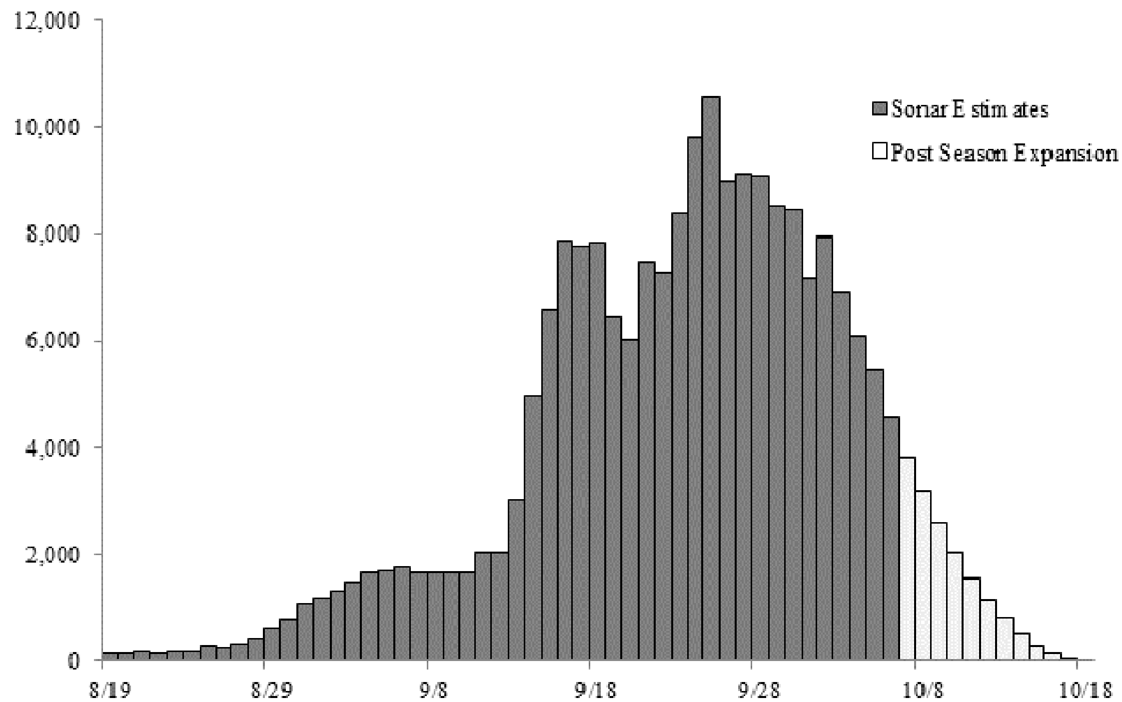


Figure 13.–Daily sonar estimates for Chinook salmon, July 6 through August 18, 2013 (top), and daily sonar estimates with postseason fall chum salmon expansion estimates for fall chum salmon, August 19 through October 18, 2013 (bottom).

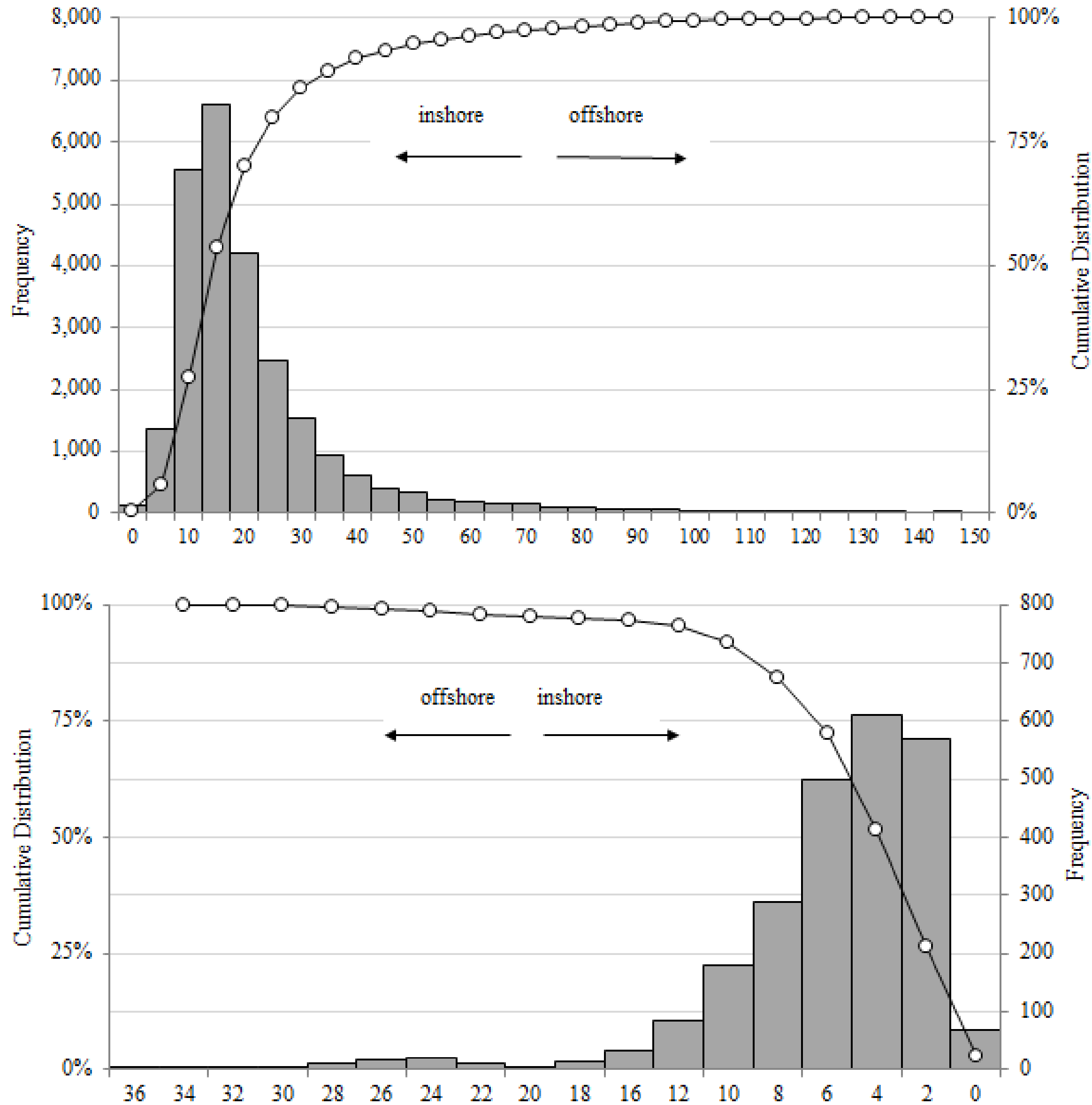


Figure 14.–Left bank (top) and right bank (bottom) horizontal distribution of upstream Chinook salmon passage in the Yukon River at Eagle sonar project site, July 4 through August 18, 2013.

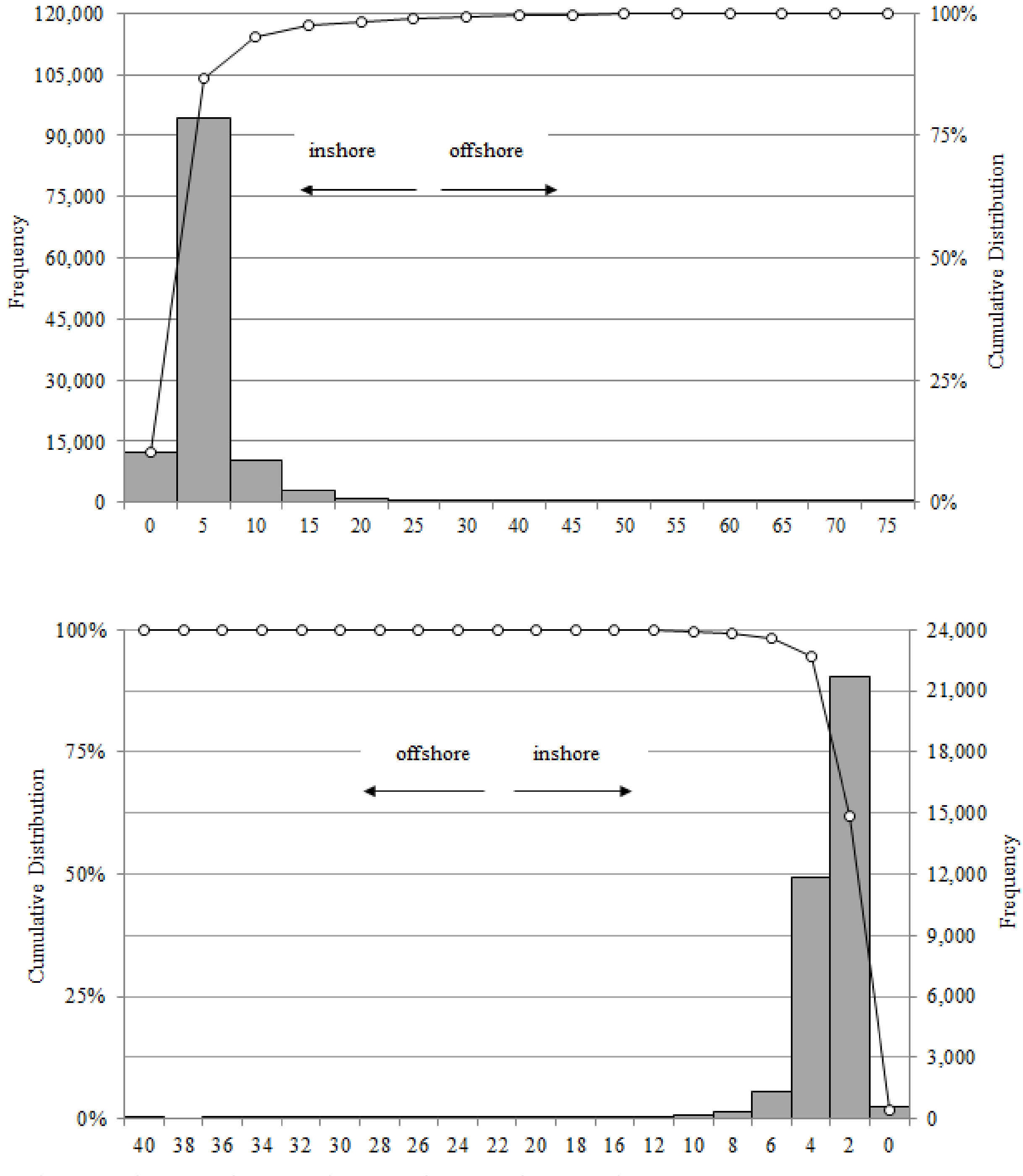


Figure 15.–Left bank (top) and right bank (bottom) horizontal distribution of upstream fall chum salmon passage in the Yukon River at Eagle sonar project site, August 19 through October 6, 2013.

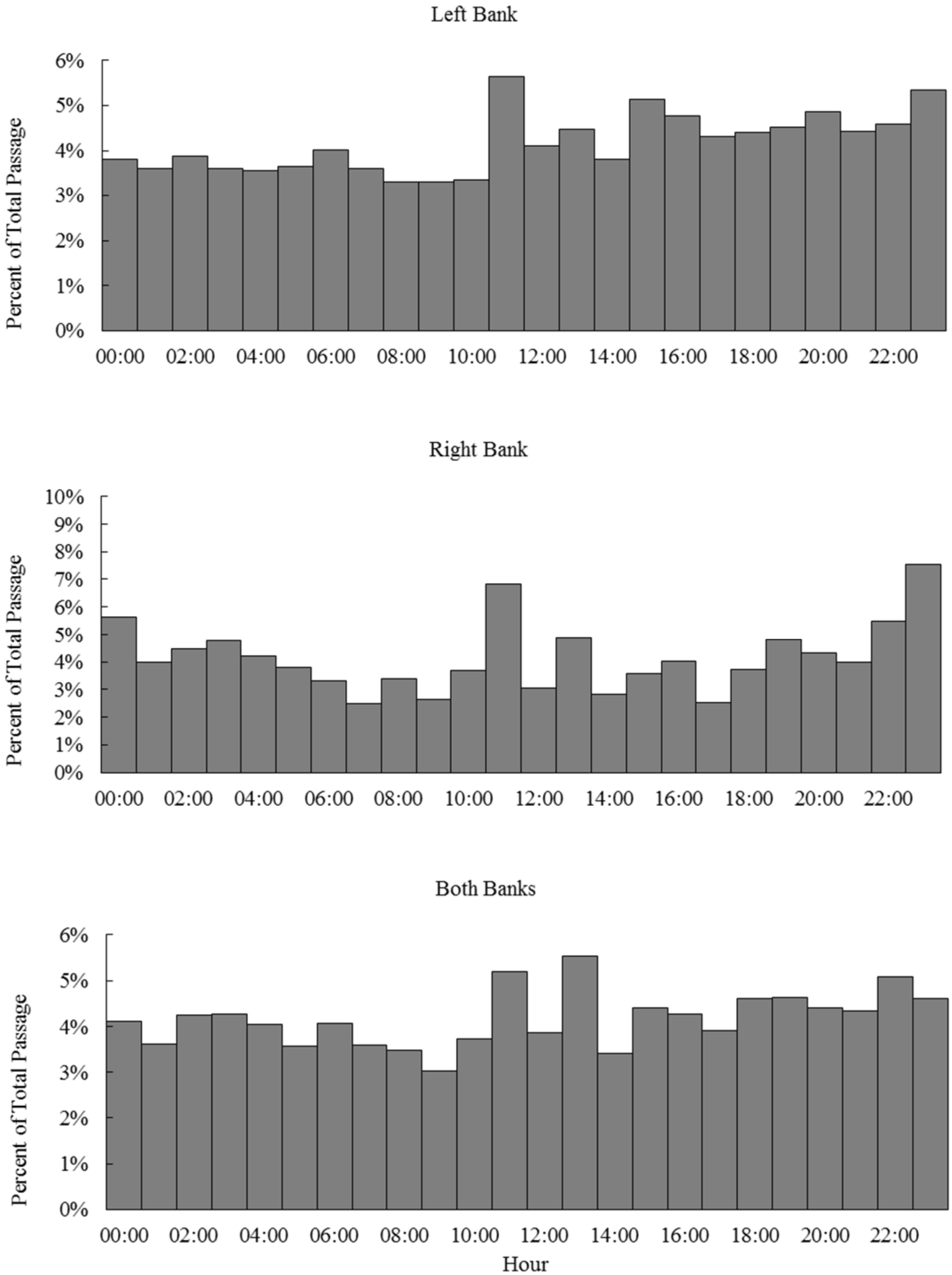


Figure 16.–Hourly Chinook salmon passage observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from July 6 through August 18, 2013.

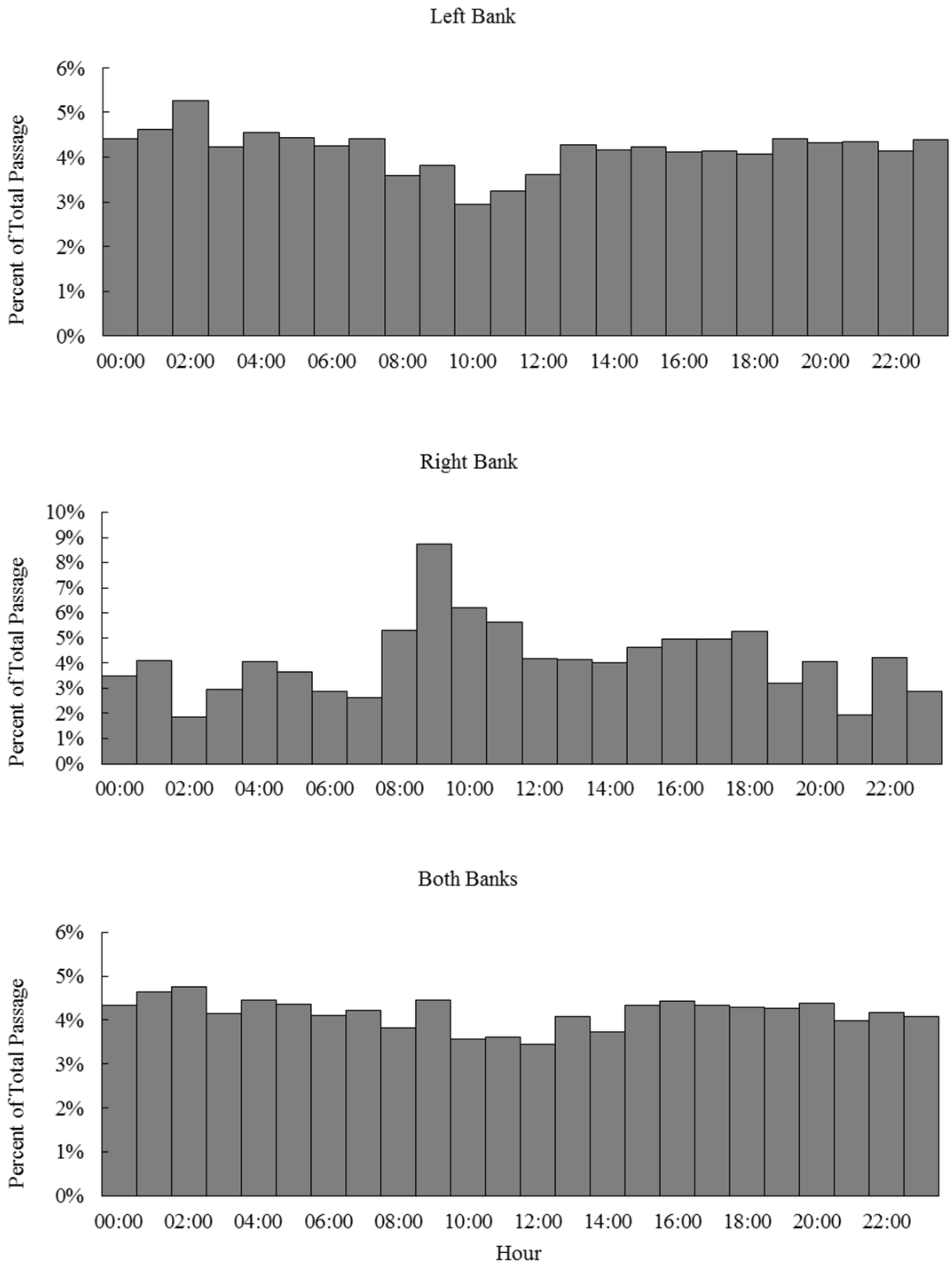


Figure 17.–Hourly fall chum salmon passage observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from August 19 through October 6, 2013.

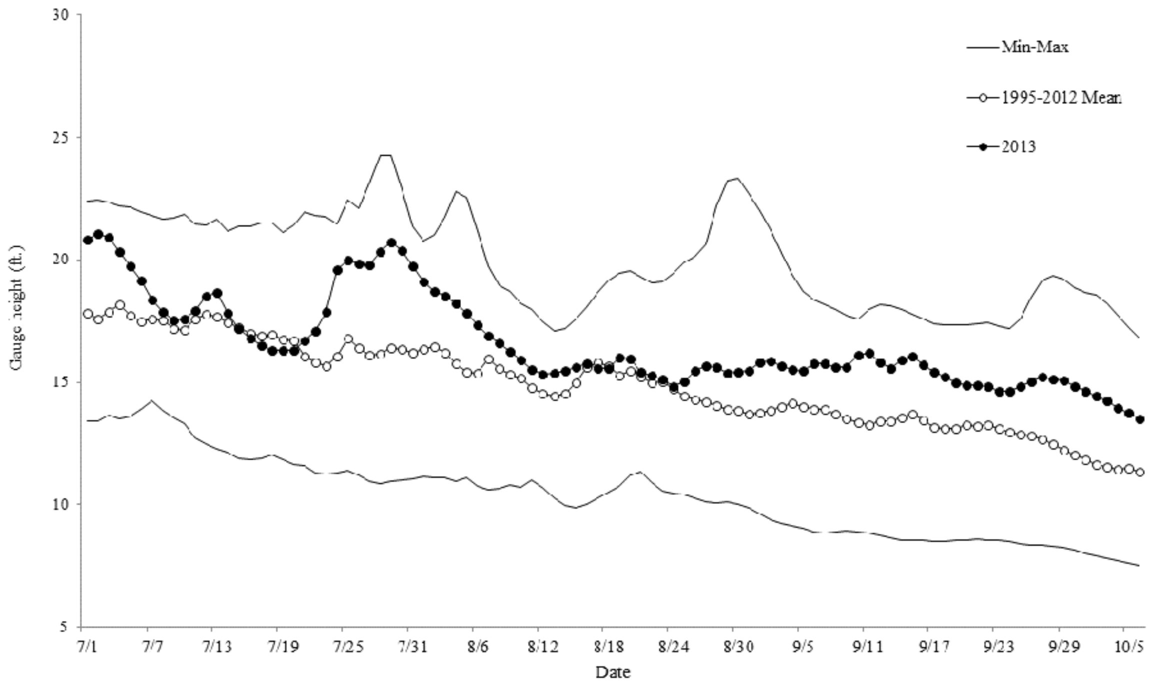


Figure 18.–Yukon River daily water level during the 2013 season at the Eagle water gage compared to minimum, maximum, and mean gage height from 1995 to 2012.

Source: United States Geological Survey.

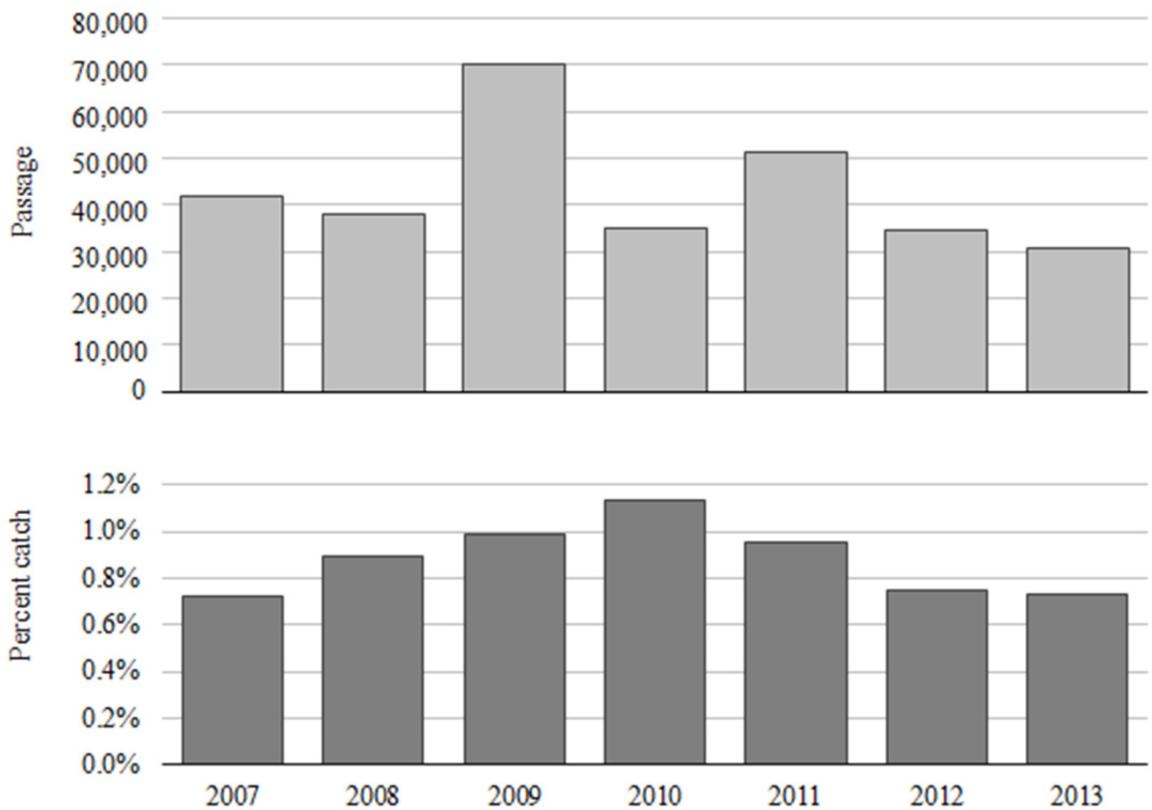


Figure 19.–Percent of Chinook salmon catch during Chinook salmon sampling compared to the total cumulative passage estimates at the Eagle sonar project, on the Yukon River.

APPENDIX A: CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix A1.–Climate and hydrologic observations recorded at 1800 each day, Eagle sonar project site, Yukon River, 2013.

	Precipitation	Wind		Sky	Temperature (C°)	
Date	(code)[a]	Direction	Speed (mph)	(code)[b]	Air	Water[c]
7/06	A	ND	ND	S	ND	ND
7/07	A	N	4.5	C	22.7	ND
7/08	B	N	11.0	O	17.1	ND
7/09	B	E	4.5	B	17.2	ND
7/10	B	SW	7.2	B	18.4	ND
7/11	A	SE	8.5	S	20.5	ND
7/12	A	SE	5.2	C	23.2	ND
7/13	A	SE	0.9	C	25.2	14.0
7/14	A	SE	3.1	C	28.0	15.0
7/15	A	SE	0.9	B	26.4	15.0
7/16	A	SE	3.0	B	25.0	16.0
7/17	A	SE	0.6	B	21.3	16.0
7/18	A	S	3.2	B	24.8	17.0
7/19	B	SE	2.7	B	20.8	14.0
7/20	A	SE	6.6	B	18.5	18.0
7/21	A	SE	6.3	B	18.1	16.0
7/22	A	SE	2.1	C	21.4	17.5
7/23	A	SE	2.5	S	22.8	15.5
7/24	A	N	2.2	B	20.1	15.0
7/25	A	SE	5.7	C	20.6	14.5
7/26	A	Calm	0.0	B	21.7	15.0
7/27	B	NW	3.2	B	19.0	15.0
7/28	A	NW	1.0	C	31.6	16.0
7/29	A	SE	0.9	S	25.1	15.5
7/30	A	SE	1.6	S	30.1	16.5
7/31	A	SE	4.6	C	30.4	17.5
8/01	A	NW	5.9	C	28.7	17.0
8/02	A	N	6.5	C	29.8	18.0
8/03	A	N	4.5	B	26.4	17.5
8/04	A	S	7.0	S	25.0	16.0
8/05	A	NE	2.0	C	18.0	17.0
8/06	A	S	4.0	S	25.0	17.0
8/07	A	Calm	0.0	B	21.0	16.0
8/08	A	N	7.0	B	23.5	15.5
8/09	A	NW	7.0	B	23.8	16.0
8/10	A	NW	3.0	B	25.4	17.0
8/11	A	SE	4.5	C	26.1	18.0
8/12	A	SE	1.5	C	25.9	19.5
8/13	A	SE	1.8	C	25.3	19.0
8/14	A	SE	2.0	S	25.4	19.5
8/15	A	NW	3.5	B	25.0	19.5
8/16	A	NW	3.5	C	25.4	18.5
8/17	A	NW	2.3	S	22.3	18.0
8/18	A	NW	4.3	O	15.5	15.0

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Appendix A1.–Page 2 of 3.

Date	Precipitation (code)[a]	Wind Direction	Wind Speed (mph)	Sky (code)[b]	Temperature (C°) Air	Temperature (C°) Water[c]
8/19	A	S	1.5	B	18.4	15.5
8/20	B	SW	0.5	O	14.0	13.5
8/21	A	N	4.0	S	14.0	14.0
8/22	A	N	5.0	B	17.0	14.0
8/23	B	N	3.0	O	13.0	13.0
8/24	A	Variable	8.0	B	8.0	12.0
8/25	A	W	3.0	C	10.0	12.0
8/26	A	W	2.0	C	9.0	12.0
8/27	A	SW	4.0	S	10.0	12.0
8/28	B	W	2.8	B	10.0	11.0
8/29	B	W	3.1	B	11.2	11.0
8/30	B	SE	3.6	O	12.0	11.0
8/31	B	S	3.2	B	9.1	10.5
9/01	A	E	1.9	B	11.7	10.5
9/02	B	NW	2.2	B	12.4	10.5
9/03	A	NW	9.1	S	16.8	12.0
9/04	B	NW	1.6	B	14.0	11.5
9/05	A	SE	3.5	B	16.6	11.5
9/06	B	Calm	0.0	O	17.0	10.5
9/07	A	Calm	0.0	B	18.6	12.0
9/08	C	SE	6.2	O	8.4	9.0
9/09	A	SE	4.4	S	9.2	9.0
9/10	A	NW	4.4	B	17.7	9.0
9/11	A	NW	3.9	B	16.3	9.5
9/12	A	NW	2.2	C	16.1	9.0
9/13	A	NW	3.5	B	15.5	10.0
9/14	B	SE	5.0	S	12.0	9.5
9/15	A	E	5.4	C	10.5	8.0
9/16	A	Variable	5.5	C	6.0	6.0
9/17	B	SE	4.2	O	4.3	5.5
9/18	B	SE	2.3	O	2.9	5.0
9/19	D	Calm	3.0	O	0.0	5.0
9/20	A	Calm	0.0	B	-1.0	5.0
9/21	A	Calm	0.0	O	-0.5	6.0
9/22	F	N	5.0	O	-1.0	5.0
9/23	ND	ND	ND	ND	ND	ND
9/24	A	SE	6.1	O	3.5	4.0
9/25	A	SE	9.2	O	2.7	4.0
9/26	A	S	7.4	O	4.4	4.5
9/27	A	SE	2.4	C	1.4	4.0
9/28	A	Calm	0.0	B	4.5	4.0

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Appendix A1.–Page 3 of 3.

Date	Precipitation (code)[a]	Wind Direction	Wind Speed (mph)	Sky (code)[b]	Temperature (C°) Air	Temperature (C°) Water[c]
9/29	A	NE	2.5	B	3.2	3.0
9/30	A	NW	5.3	O	4.3	4.0
10/01	A	Calm	0.0	ND	4.5	2.0
10/02	A	Calm	0.0	C	3.5	3.0
10/03	A	Calm	0.0	S	4.0	5.0
10/04	A	N	3.5	B	2.5	4.0
10/05	A	Calm	0.0	B	2.0	4.0
10/06	A	Calm	0.0	B	4.0	4.0

Note: ND indicates that no data were collected.

[a] Precipitation code for the preceding 24 h period: A = none; B = intermittent rain; C = continuous rain; D = snow and rain mixed; E = light snowfall; F = continuous snowfall; G = thunderstorm w/ or w/o precipitation.

[b] Instantaneous cloud cover code: C = clear, cloud cover < 10% of sky; S = cloud cover < 60% of sky; B = cloud cover 60–90% of sky; O = overcast (100%); F = fog, thick haze or smoke.

[c] Water temperature collected approximately 30 cm below surface with pocket thermometer.

APPENDIX B: SPECIES COMPOSITION TEST FISHERY CATCH, CPUE, AND SMOOTHED DATA BY DAY AND SALMON SPECIES

Appendix B1.–Species composition test fishery catch, CPUE, and smoothed data, by day and salmon species, Eagle sonar project, Yukon River, 2013.

		Chinook salmon					Chum salmon			
Date	Large mesh fathom-hours	Catch	CPUE	Catch smoothed	CPUE smoothed	Small mesh fathom-hours	Catch	CPUE	Catch smoothed	CPUE smoothed
8/01	16.33	2	0.12	4.24	0.25	17.06	0	0.00	0.36	0.02
8/02	17.08	8	0.47	4.14	0.24	15.90	1	0.06	0.39	0.02
8/03	16.62	4	0.24	4.04	0.24	15.45	0	0.00	0.42	0.03
8/04	16.46	6	0.36	3.91	0.23	16.75	1	0.06	0.45	0.03
8/05	18.29	9	0.49	3.70	0.22	18.12	0	0.00	0.51	0.03
8/06	17.29	2	0.12	3.51	0.21	16.64	0	0.00	0.55	0.03
8/07	17.14	3	0.18	3.22	0.19	16.51	0	0.00	0.61	0.04
8/08	16.26	1	0.06	2.86	0.17	17.46	1	0.06	0.69	0.04
8/09	16.55	2	0.12	2.47	0.15	16.99	3	0.18	0.73	0.04
8/10	16.27	0	0.00	2.09	0.12	16.78	0	0.00	0.65	0.04
8/11	16.71	2	0.12	1.72	0.10	16.69	1	0.06	0.56	0.03
8/12	16.58	1	0.06	1.40	0.08	16.36	0	0.00	0.40	0.02
8/13	16.79	1	0.06	1.20	0.07	16.21	0	0.00	0.23	0.01
8/14	16.66	2	0.12	1.03	0.06	16.19	0	0.00	0.09	0.01
8/15	15.94	1	0.06	0.88	0.05	15.97	0	0.00	0.08	0.01
8/16	15.67	0	0.00	0.67	0.04	16.39	0	0.00	0.08	0.00
8/17	16.07	1	0.06	0.52	0.03	16.01	0	0.00	0.12	0.01
8/18	16.01	0	0.00	0.34	0.02	15.97	0	0.00	0.20	0.01
8/19	15.90	0	0.00	0.19	0.01	16.17	1	0.06	0.32	0.02
8/20	15.83	0	0.00	0.11	0.01	16.07	0	0.00	0.45	0.03
8/21	16.47	0	0.00	0.06	0.00	16.31	0	0.00	0.62	0.04
8/22	16.45	0	0.00	0.06	0.00	16.42	1	0.06	0.86	0.05
8/23	15.98	0	0.00	0.08	0.01	16.31	1	0.06	1.11	0.07
8/24	16.72	0	0.00	0.11	0.01	16.28	2	0.12	1.51	0.09
8/25	16.60	0	0.00	0.13	0.01	16.23	1	0.06	2.01	0.12
8/26	16.02	1	0.06	0.15	0.01	16.51	2	0.12	2.56	0.15
8/27	15.81	0	0.00	0.13	0.01	16.36	1	0.06	3.28	0.19
8/28	15.61	0	0.00	0.10	0.01	16.41	6	0.37	4.16	0.24
8/29	15.87	0	0.00	0.08	0.00	16.26	3	0.18	4.98	0.30
8/30	16.03	0	0.00	0.06	0.00	16.06	2	0.13	5.96	0.36
8/31	15.94	0	0.00	0.03	0.00	16.65	9	0.54	7.01	0.43

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Appendix B1.–Page 2of 2.

		Chinook salmon					Chum salmon			
Date	Large mesh fathom-hours	Catch	CPUE	Catch smoothed	CPUE smoothed	Small mesh fathom-hours	Catch	CPUE	Catch smoothed	CPUE smoothed
9/01	15.69	0	0.00	0.02	0.00	16.73	7	0.42	8.05	0.5
9/02	16.12	0	0.00	0.01	0.00	16.93	11	0.65	9.02	0.56
9/03	16.14	0	0.00	0.01	0.00	16.84	4	0.24	10.15	0.63
9/04	15.71	0	0.00	0.00	0.00	17.21	14	0.81	11.20	0.68
9/05	16.25	0	0.00	0.00	0.00	17.19	13	0.76	12.27	0.75
9/06	10.93	0	0.00	0.00	0.00	5.62	5	0.89	13.30	0.81
9/07	14.08	0	0.00	0.00	0.00	13.48	20	1.48	14.32	0.87
9/08	16.03	0	0.00	0.00	0.00	16.41	7	0.43	15.45	0.94
9/09	16.60	0	0.00	0.00	0.00	17.01	9	0.53	16.56	1.01
9/10	16.30	0	0.00	0.00	0.00	18.16	16	0.88	17.80	1.09
9/11	17.17	0	0.00	0.00	0.00	17.51	19	1.09	19.14	1.17
9/12	15.41	0	0.00	0.00	0.00	16.97	21	1.24	20.76	1.26
9/13	16.10	0	0.00	0.00	0.00	16.44	19	1.16	22.37	1.34
9/14	16.39	0	0.00	0.00	0.00	17.20	24	1.40	24.19	1.44
9/15	16.76	0	0.00	0.00	0.00	17.25	27	1.57	25.88	1.54
9/16	15.46	0	0.00	0.00	0.00	17.11	39	2.28	27.29	1.63
9/17	14.46	0	0.00	0.00	0.00	16.26	26	1.60	28.52	1.71
9/18	14.75	0	0.00	0.00	0.00	18.42	39	2.12	29.67	1.79
9/19	14.56	0	0.00	0.00	0.00	15.27	23	1.51	30.53	1.84
9/20	14.08	0	0.00	0.00	0.00	19.01	48	2.53	31.15	1.88
9/21	14.56	0	0.00	0.00	0.00	15.64	28	1.79	31.68	1.9
9/22	15.05	0	0.00	0.00	0.00	16.21	36	2.22	31.92	1.92
9/23	14.02	0	0.00	0.00	0.00	15.80	30	1.90	31.86	1.92
9/25	14.88	0	0.00	0.00	0.00	15.19	18	1.19	31.38	1.92
9/26	13.99	0	0.00	0.00	0.00	17.11	38	2.22	31.14	1.92
9/27	15.13	0	0.00	0.00	0.00	16.82	38	2.26	30.95	1.92
9/28	14.14	0	0.00	0.00	0.00	16.40	31	1.89	30.76	1.92
9/29	14.05	0	0.00	0.00	0.00	14.96	23	1.54	30.57	1.92
9/30	13.41	0	0.00	0.00	0.00	15.71	33	2.10	30.39	1.92

APPENDIX C: EAGLE SONAR SPECIES CROSSOVER DATE MEMORANDUM

Appendix C1.–Eagle sonar species crossover date memorandum.

THE STATE of ALASKA

GOVERNOR SEAN PARNELL

Department of Fish and Game

DIVISION OF COMMERICAL FISHERIES

Fairbanks Field Office
1300 College Road
Fairbanks, AK 99701-1551
Main: 907.459.7274
Fax: 907.459.7271

AYK Regional Office
333 Raspberry Road
Anchorage, AK 99518-1565
Main: 907.267.2105
Fax: 907.267.2442

MEMORANDUM

TO: Yukon Staff
(See Distribution)

DATE: February 26, 2014

SUBJECT: Eagle Sonar Species Crossover Date

FROM: Jody Lozori
Fishery Biologist II
Fairbanks

Introduction

This memo investigates an alternative approach for determining the species crossover date for Chinook and fall chum salmon at the Eagle sonar project. Alternative methods of determining the crossover date are under consideration due to concerns over biased estimates caused by unequal run sizes and sparse catch data collected during the crossover period.

Since Chinook and fall chum salmon runs are considered discrete in time, sonar counts are not apportioned by species, but rather a specific date is assigned after evaluation of catch from the project's species composition fishery. Because some temporal overlap does occur, the current method of determining this date (which assumes fishing effort for both species is identical) uses reverse-cumulative plots of Chinook and chum salmon catches.

Estimates are reported as Chinook for days d, such that:

$$\sum_{d=n,i=Chinook}^{d} C_{id} > \sum_{d=1,i=chum}^{d} C_{id}$$

where n is most current day of fishing and C is the catch of species i on day d. The species crossover date is defined as the day where the inequality is no longer met.

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With sparse catches and the possibility of outliers in the catch data, there is a concern that anomalous observations may have a disproportionate effect in determining the crossover date using reverse cumulative analysis. Also, because of numerous factors which can affect catch and effort in the test fishery, a more robust approach of determining catch effort is needed to determine proportional abundance of Chinook and fall chum salmon.

The alternative approach is to use catch per unit effort (CPUE) for both large and small fathom nets from the species composition test fishery. The data will then be plotted, and the relationship between the variables summarized using a smoothing algorithm.

The first approach will use catch data as the current method does, but will standardize effort rather than assuming catch effort is equal for both mesh sizes during the test fishery. The second approach will smooth outliers in the series and limit the outlier's impact on the forecast of the crossover date.

Methods

Traditional CPUE measures were calculated for each day *d* on the left bank during species composition fishing using 2 specific gillnet mesh sizes. Chinook salmon CPUE was calculated on the catch and effort of the large mesh gillnet (7.5-inch); chum salmon CPUE was calculated on the catch and effort of the small mesh gillnet (5.25-inch). All nets were 25 fathoms (45.7 m) in length and CPUE estimates are reported as catch per fathom hour.

CPUE data for Chinook and fall chum salmon were imported into *R*[1] and scatter plots from the data were smoothed using Friedman's supersmoother algorithm[2]. The algorithm first computes 3 separate smooth curves from the input data with symmetric spans of 0.05**n*, 0.2**n* and 0.5**n* (where *n* is the number of data points), then selects the best of the three smooth curves for each predicted point using leave-one-out cross validation. The curves are then smoothed by a fixed-span smoother (span = 0.2*n) and the prediction is computed by linearly interpolating between the three smooth curves. This final smooth curve is then smoothed again with a fixed-span smoother (span = 0.05*n).

Results

In 2013, sparse catch data shifted the in-season crossover date back from August 19 to August 13 in post-season analysis, even though chum salmon were not caught from August 12 through August 19, and Chinook salmon were still being sampled in the test fishery (Figure 1 and 2).

[1] R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, available for download: http://www.R-project.org

[2] Friedman, J. H. (1984). A Variable Span Smoother. Tech. Rep. No. 5, Laboratory for Computational Statistics, Dept. of Statistics, Stanford

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Yukon Staff February 26, 2014

Proportions of daily CPUE and catch data for both Chinook and chum salmon were also plotted using the smoothing algorithm. Both plots were identical and predict August 19 as the crossover date, which is in agreement with the in-season forecast (Figure 3).

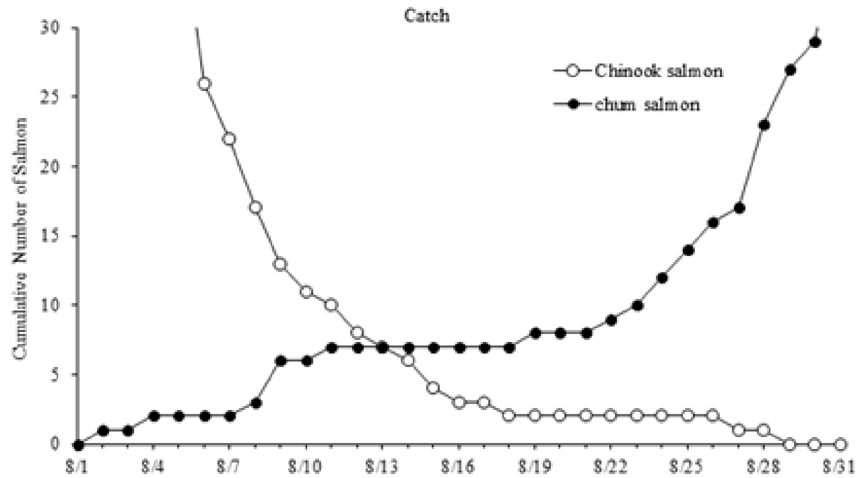

Figure 1.-Species changeover date of August 13 determined by using traditional reverse-cumulative calculations of catch at the Eagle sonar project site, 2013.

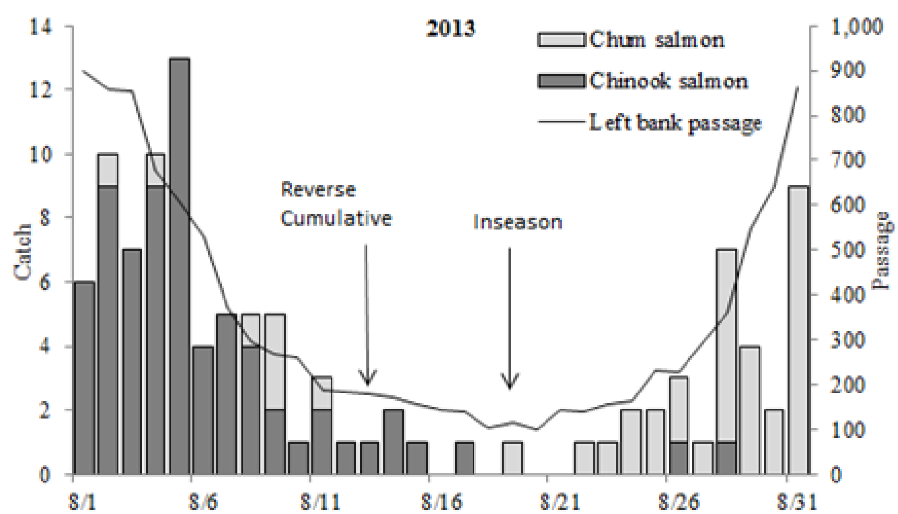

Figure 2.-Left bank passage, daily catch by species, and in-season / post season (determined by using reverse-cumulative) crossover dates at the Eagle sonar project, on the Yukon River, 2013.

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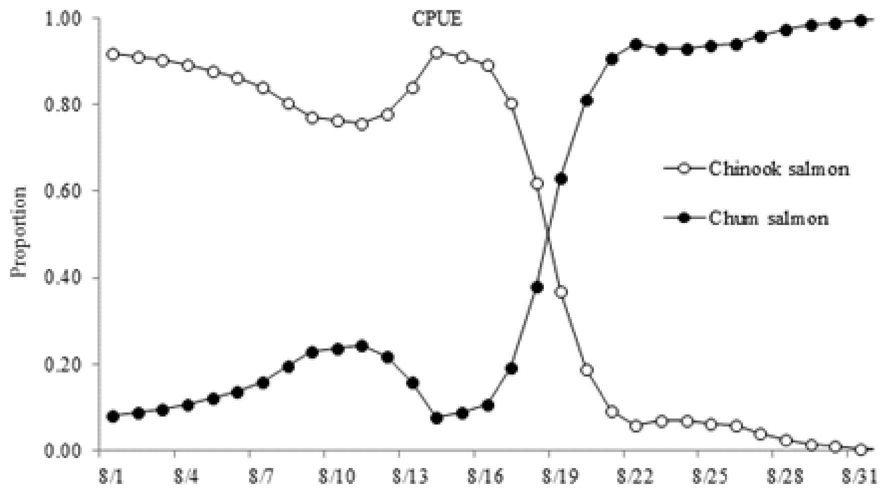

Figure 3.-Species changeover date August 19 determined by applying smoothing algorithm to Chinook and chum salmon CPUE at the Eagle sonar project, on the Yukon River, 2013.

Discussion

After evaluating conclusions from both the reverse cumulative and smoothed CPUE analysis, we have determined that using CPUE from the species composition test fishery is a better fit than the reverse cumulative of catch to determine the crossover date. CPUE, which is assumed to be proportional to abundance, seems more defensible in regard to measuring catch effort in predicting the crossover date. Additionally, eliminating outliers by smoothing the catch data reduces bias and provides for a better prediction of the crossover.

When applied to 2007-2012 estimates, this analysis does change both Chinook and chum salmon estimates, but considering crossover dates are made inseason, fishery management decisions in the United States and Canada most likely would have not have been affected. Except for 2008, which suggests a decrease in the Chinook estimate of 2,702 fish (- 7.63% of the total Chinook salmon passage estimate), all other yearly estimates only suggest a change of ± 3.5% of the total Chinook salmon estimate (Table 1). It is not our intention to adjust previous year estimates, but apply this methodology in the future.

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Yukon Staff February 26, 2014

Table 1.-Comparison of reverse cumulative and smoothed CPUE crossover data at the Eagle sonar project, on the Yukon River.

	Crossover date		Chinook salmon		Chum salmon[b]	
	Reverse cumulative	Smoothed CPUE	Reverse cumulative	Smoothed CPUE	Reverse cumulative	Smoothed CPUE
2007[a]	22-Aug	1-Sep	41,697	43,126	235,871	234,442
2008	16-Aug	11-Aug	38,097	35,395	171,347	174,049
2009	20-Aug	12-Aug	69,957	68,780	95,462	96,639
2010	19-Aug	16-Aug	35,074	34,364	125,547	126,257
2011	12-Aug	13-Aug	51,271	51,503	212,162	211,930
2012	19-Aug	21-Aug	34,747	35,009	147,710	147,448
2013	13-Aug	18-Aug	29,823	30,725	201,656	200,754

[a] First year reverse cumulative was used to determine cross over date.
[b] Estimates do not include expansion for fish that may have passed after sonar operations ceased.

Distribution: Borba, Conitz, Estensen, Hamazaki, McIntosh, Newland, Pfisterer, Schmidt